Segmentation in the *HSI* Color Space Dedicated for Medical Imaging

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Abstract

This study is about 3D scanner conception dedicated to human foot modelling. It is composed by digital devices. The reconstruction method used is based on a stereovision technique. In order to obtain a 3D reconstruction of the patient foot, it is absolutely necessary to extract and reproduce accurately its shape. Consequently, a segmentation stage is unavoidable and requires a specific algorithm given that standard algorithms do not provide enough satisfactory results. Moreover, the environment definition (background color, lighting conditions) depends on the envisaged method. The comparison of the *RGB* components of several foot skin has shown a weak occurrence of the blue component. A colorimetric study was done using a set of backgrounds with different referenced blue colors (Pantone®). The study was done in the *HSI* color space allowing the decorrelation of the *RGB* components. A set of images were acquired while combining several foot with different types and different blue backgrounds. So, the study of the hue component obtained shows a perfect uniformity with a sufficiently high saturation component which allows a first segmentation.

1. Introduction

Among human senses, the vision is probably the most fascinating [ST97]. In order to capture the perceived scene, number of works have been dedicated to image acquisition. The availability of acquisition system with low prices has allowed their exploitation to provide solutions for different fields such as publishing, medical applications, aerospatial applications, ...

In this way, the study belongs to a project of developing 3D acquisition system. This last is dedicated to biomedical applications related to Orthopaedic sciences [MRF03, MRF01]. The aimed system need to be able to extract the foot metrology[1] with a precision of 1 mm. Currently, the foot measures are done by the expert and the precision does not go under 4 mm.

[1] A set of measures allowing to represent accurately the foot surface.

1.1. Problematic

Several types of acquisition systems exist. They are based on different techniques such as laser triangulation, telemetry, *etc*. The systems mentioned above do not give results related to vision (images). In order to respect the specifications of this project, we have chosen to stay in a framework of vision systems. Hence, our system is composed by several digital cameras arranged around the foot acquisition platform. The chosen approaches of digitalization and 3D reconstruction are represented by the stereovision [Zha97] and the reconstruction method developed in [MRF02] based on projections. In order to handle both simple pathologies and more important ones, the reconstruction resolution is increased thanks to the combination of the two methods described above and given by figure 1.

These different approaches are both based on the reconstruction of a 3D object starting from 2D images. In our case, the object to be reconstructed is the human foot. In order to use correctly the acquired images, a stage of preprocessing is very suitable. After that, a segmentation step has to be done in order to extract the foot representative pixels.

One of the main constraints consists on the facts that the system must be completely automatic and user-friendly. Moreover, it has to work on any type of feet (different pathologies or skin colors).

1.2. Overview

Image segmentation is a well-know problematic. Several works have been devoted to the development of different techniques [MW87]. The aim of the envisaged technique is to obtain two modalities starting from an acquisition of the patient foot. These two modalities are represented by the foot and the background.

The color is an important characteristic when defining of the system specifications. The *RGB* has been the first color space we used for our first experiments. In these lasts, the application of standard methods has shown their ineffectiveness. Consequently, it seemed to us very inter-

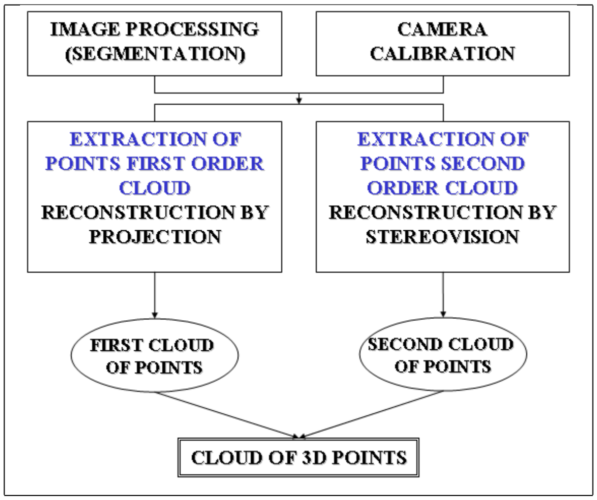

Figure 1: *Synoptic scheme of the acquisition system.*

esting to try other color spaces in order to find a better representation giving satisfactory results. It is known that the skin has a specific range of hues. Moreover, skin segmentation has been and still until nowadays a challenging and very delicate problem. For these needs, several models have been described in the literature [RK82, Wes78, SSW88, CP95].

The remainder of this paper is organized as follow : the second section consists in the description of the followed methodology in order to study the different skin types. It is done with the view to select the optimal acquisition conditions and the best color space to ease the segmentation stage.

The third section is devoted to the experimentation and the interpretation of the obtained results. Finally, a conclusion and a brief description of future works are given.

2. Our methodology

The study is done on several kinds of feet. In this paper, only three feet given by figure 2 have been kept for the study. One of the most important adjustments for the segmentation stage consists in the acquisition conditions [PL01]. This topic is described in the next section.

2.1. Acquisition conditions

Our acquisition system is composed of 4 digital cameras in addition to a linear one. This system gives 5 *RGB* color images with high resolutions. In the optic to adjust the lighting conditions, we have used a diffuse lighting.

A particular lighting has to be found in order to make a reliable reproduction of the skin texture and color. This lighting must also avoid shading addition with the view to keep an accurate shape of the foot. The figure 3 gives a decreasing succession of three lighting. Notice that the last image offers the best compromise.

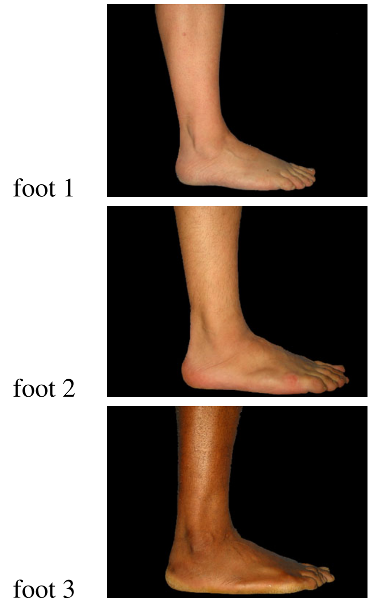

Figure 2: *The three feet used for experimentation.*

Figure 3: *Dependance between acquisition quality and lighting conditions.*

A good segmentation can be obtained if and only if the background of the acquisition system has been well-defined. So, a study on the combination between the background color and the lighting should allow to define the optimal conditions.

2.2. Color representation space

In the framework of vision systems, the choice of an adapted color representation is certainly very delicate [Lar02]. Because of the nature of the acquisition system, the *RGB* color space is the most frequently used. It describes the color as the combination of three correlated primary colors (Red, Green and Blue). Another representation allows to avoid problems related to lighting variations. It represents the color in a similar way as the human visual system i.e. a Hue (H), a Saturation (S) and an Intensity (I). In this way, representing the color in the *HSI* color space seems very interesting. The *I* component describes the gray-level intensity with the view to express if the color is fair or dark. The H component characterizes the color hue and the S one measures its purity. Notice that the hue is considered as significant only if the saturation value is sufficiently high.

2.3. Segmentation method

The segmentation is divided into two approaches : contour extraction (edge detection) and region localization.

The contour approach has been tried on images obtained from our acquisition system by applying well-known operators such as Sobel, Roberts or Laplacian. However the obtained results are not very satisfactory as given by the figure 5. However, algorithms of second order such as the Canny-Deriche one are also ineffective. Nevertheless, these results could be exploited by using additional tools in order to increase the robustness.

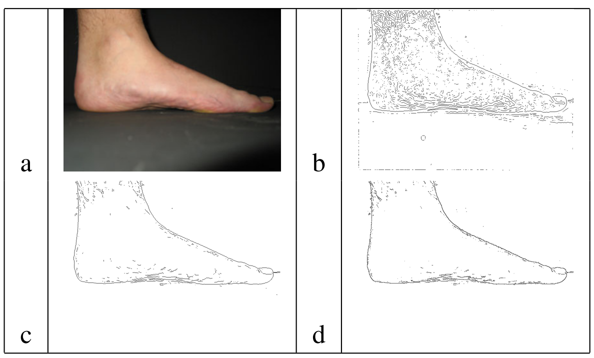

Figure 4: *Contour extraction, a : original image, b : Laplacian, c : Sobel, d : Roberts.*

2.4. Foot bottom

The foot bottom is very important for the 3D reconstruction stage. However, because of the cameras arrangement, it is impossible to capture this information. So, a linear camera was used instead of a classical camera so as to economize required space.

One of the constraints imposed by the specifications concerned the position of the patient during the acquisition process. This constraint fixes a standing position with a stay on the floor in order to simulate a real deformation. So, the foot is put on a plexiglass plate. This last is disposed between the patient foot and the linear camera. During the acquisition, it is possible to find dust and fingerprint which can generate noise in the resulting image.

The generated noise is often very difficult to model. The dust and fingerprints correspond to very small object and some pixels with high gradient.

3. Experiment

To validate the methodology described above, we have experimented the segmentation method on images obtained from the developed acquisition system. The whole experimentation data is assembled in the table 1. We have computed for each foot of the figure 2, the mean and the standard deviation of the red, the green and the blue component and the same computations for the hue, saturation and intensity. These results are interpreted in detail in the next section.

Average	Red	Green	Blue	H	I	S
Background a	118	117	112	34	115	8
Background b	85	106	120	8	102	53
Background c	86	131	150	30	122	80
Background d	103	116	118	15	112	26
Foot 1	191	132	94	56	139	84
Foot 2	186	123	78	56	129	146
Foot 3	149	84	40	57	91	103

Standard dev.	Red	Green	Blue	H	I	S
Background a	21	19	17	22	19	2
Background b	29	22	21	15	23	23
Background c	24	22	20	0	21	19
Background d	27	22	20	25	23	14
Foot 1	31	25	20	1	25	13
Foot 2	28	22	19	1	23	10
Foot 3	33	25	17	1	24	29

Table 1: *Average and standard deviation values of RGB and HSI components for the four backgrounds and the three feet.*

3.1. Results with skin

The study of the hue component for the skin obtained shows a perfect uniformity with a sufficiently high saturation component (table 1).

From the other side, no conclusion could be taken for the red, green and blue components values except that the comparison of the components of several foot skin has shown a weak occurrence of the blue component. The low value of the blue component lets us assume that the blue color is weakly present in the skin in comparison with the green or the red component. This assumption is confirmed by the figure 6 which shows a spatial representation of colors in the *RGB* cube where the blue is practically absent.

The idea is so to use a blue as a background color. Consequently, it is necessary to experiment different blue colors in order to find the optimal conditions when combine with lighting.

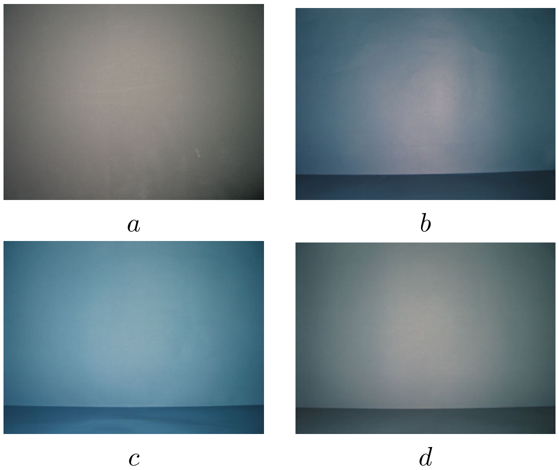

Figure 5: *Acquisition with the four selected backgrounds.*

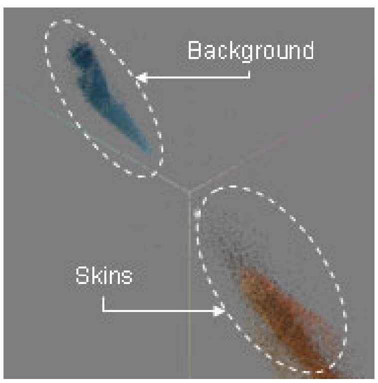

Figure 6: *Spatial representation of the feet and background colors in the* RGB *color space.*

3.2. Results with background

Four background colors have been selected in this paper (figure 5). Twenty blue backgrounds have been experimented. However, four of them the more representative have been chosen. The backgrounds "b", "c", and "d" are blue backgrounds taken from the *Pantone*® range and having the following references : 540 for "b", 542 U for "c", 548 U for "d". The background a was chosen as black in order to compare the results with blue backgrounds. The figure 7 shows the hue and saturation components of retained backgrounds.

For the background "a", the hue is non-uniform and has a value that cannot be taken into account because the saturation is very weak. The obtained color for each background is the combination of the light and the background color. Moreover, the white and the black colors are achromatic and so their hue is non-significant. In the case of the background "a", the average values obtained for the red, blue and green components are : R_a=118, G_a=117, B_a=112. It is corresponding approximatively to a grey value. Consequently, the saturation component is not high enough to take into account the hue value (S_a = 8).

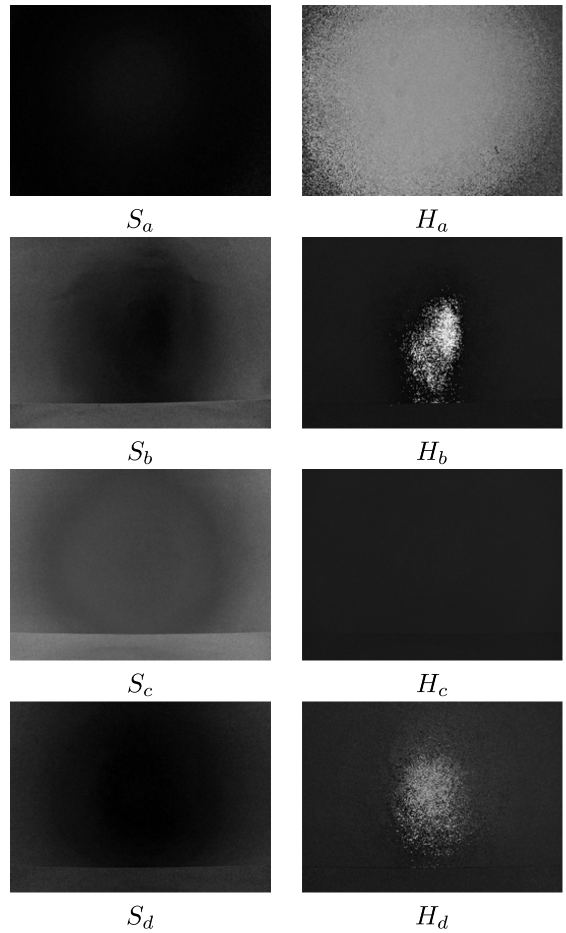

Figure 7: *Saturation and hue of the four backgrounds (a, b, c and d).*

For the others backgrounds, "c" shows good characteristics. Its saturation value is relatively high and its hue value is uniform in the image. The others colors do not show an uniform hue or a sufficiently high saturation ($20 \leq S_b \leq 53$) (figures 7 and 9). Moreover, the saturation value of background "c" is sufficiently high (S_c=80) to take into account the hue component. The background "c" seems to be the best color which presents the best characteristics and which help us in the first segmentation stage (see figure 9-H_c). For the other backgrounds, the hue is not a reliable value. The non-homogeneity shown on figures 7, 9 corresponds to light reflection on the background.

The next step is to experiment the background "c" with the different retained feet so as to validate the proposed method.

3.3. Results with skin and background

The study of the hue component obtained shows a perfect uniformity with a sufficiently high saturation component. This last is composed of three classes given by the histogram (figure 9). The first mode is constituted by an important number of pixels close to 0 which correspond to the background. The second corresponds to the skin and the third corresponds to the shade of the leg due to the lighting as well as the border between the skin and the background [WR79]. In this case, the segmentation method is trivial because it consists in a thresholding step in order to keep only the hue values corresponding to the skin. A segmentation step by hysteresis thresholding is then applied to the hue component with the view to extract the foot shape (figure 9-d). Some defects corresponding to the hairs are present in the obtained image and are eliminated by a morphological aperture operator (image 9-d, equation 1).

Finally, for each image, the foot shape is used for the reconstruction.

$$A \circ B = (A \ominus B) \oplus B \tag{1}$$

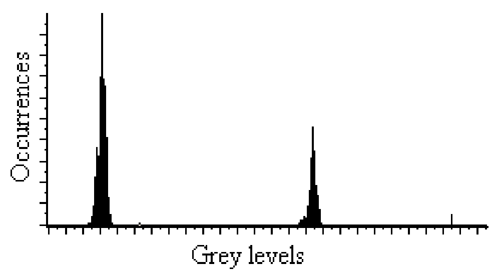

Figure 8: *Histogram of the hue component.*

Starting from the developed system, four images are obtained thanks to the cameras arranged around the foot. These images will allow us to use a technique for foot points extraction i.e. stereovision.

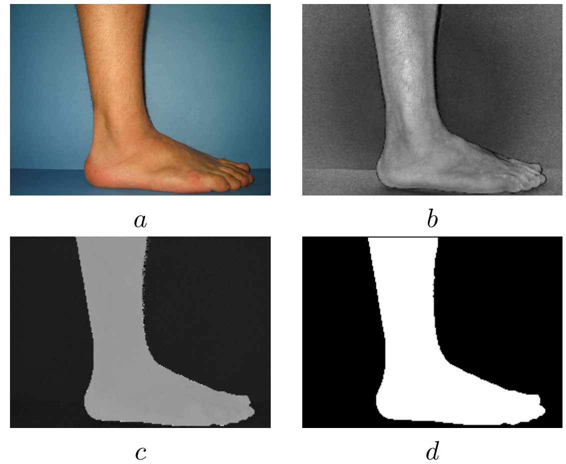

Figure 9: *a : acquisition of foot 2 with background c, b : its saturation, c : its hue, d : segmentation result.*

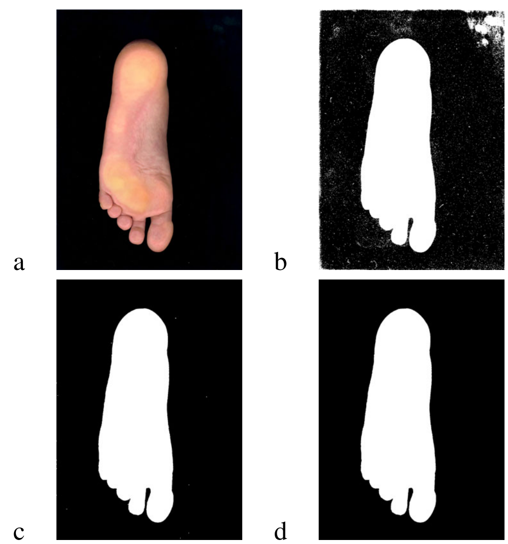

Figure 10: *a : acquisition with the linear camera, b : hue component, c : aperture operator result, d : geodesic dilatation result.*

3.4. Result for foot bottom

This study has allowed to show that the skin hue is quasi-uniform. Therefore, only the hue component of the image of the foot bottom is taken into account as shown by figure 10-b.

The direct application of the aperture operator described by equation 1 does not give satisfactory results as given by figure 10-c.

In order to avoid the defects of the last morphological operator, we have implemented a geodesic dilation. This operation consists in making a recursive erosion until the elimination of the whole noise. Then, starting from the eroded object, an iterative dilatation followed by an intersection with the original image is done. The iterative process is stopped when the error is lower than a given tolerance value (figure 10-d).

4. Conclusion

In this paper, we have described the image processing stage of our acquisition system. The study made on different types of feet has demonstrated the blue weakness in the skin and the hue component uniformity. The transformation from *RGB* to *HSI* color space has permitted to make a

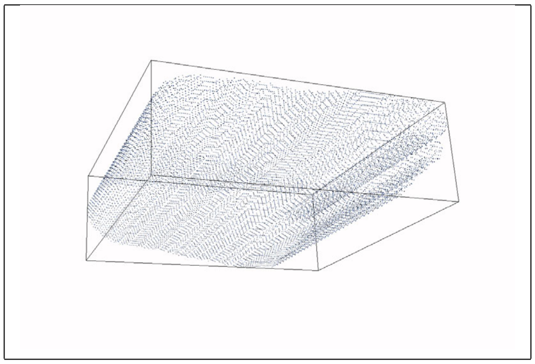

Figure 11: *First cloud of points.*

first segmentation. This result has directed us to study the use of different blue backgrounds. Only one background has been retained. It corresponds to the Pantone® *U542* reference.

After different processing, each image obtained by one of the digital camera has been perfectly segmented in order to obtain a binary shape of the foot. Following this segmentation, a matching operation between two views is done.

However, the foot bottom is obtained only from a single view and the stereovision can not be applied. So, another technique is used, it consists in projection algorithm described in [MRF02] and used for generating the image of figure 11.

Our future direction consists in an automatization of the segmentation process to be done in a real environment (cameras. . .) After that, a fusion of the different clouds of points obtained so as to reconstruct accurately the foot and extract the metrology for the orthopaedic shoe conception.

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