A New Approach to Synthesis of Static Medical Images

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Abstract

A collection of new algorithms for the synthesis of images of melanocytic skin lesion is briefly outlined. The main concept of the research is the attempt to “reverse” the role of the elements constituting the philosophy of so-called TDS-parameter (Total Dermatoscopic Score) briefly described in the paper. The applied methodology consists in executing the semantic analysis of the textual vector, describing the lesion. The same vector is used for the visual representation of the regarded lesion. It seems, that synthetic images generated by means of the developed algorithms can also be used as an alternative source of knowledge in relation to real digital images. It is assumed that the developed methodology can be applied in education of dermatology students and preferred medical doctors.

Keywords: image synthesis, TDS, melanocytic skin lesions

1 Introduction

In the past few years an increasing interest in images of melanocytic skin lesions is observed, what could be treated as a support of the visual, computer-aided diagnosis of malignant melanoma, currently one of the most dangerous type of tumors (cf. Stolz at al., 2006). On the other hand, the lack of professional computer informational databases containing images of melanocytic skin lesions is clearly noticed. Even though current technical capabilities (software and hardware) for creation and saving biomedical images, in patient’s evidence system the deficiency of attaching required digital images to patient’s charts could be observed. One of the reason is that in hospitals there is lack of properly instructed personnel, responsible for making and storage such images in the computer systems. Additionally, this situation, at least in this country, probably comes on various difficulties in the development such databases, among them owing the specific interpretation of the personal data protection act. The current assume that this act imposes the necessity to obtain patient’s approval not only for making the picture of a real lesion (either in hospital, or in clinic), but also the permission for publishing or even handing it over to another scientific research institution that specializes in processing digital images. These reasons inspired us to start the research on the
development of algorithms for the synthesis of medical images, specifically for the synthesis of static images of melanocytic skin lesions. It was assumed, that implementation of these algorithms within a special computer program system should allow to create multi-category informational database, containing both synthesized (in other words, artificial) and real images of melanocytic skin lesions.

2 Structure of the databases

In our research we use the source informational database, initially described in (cf. Hippe, 1999). Data contained in this database were collected in the Outpatient Center of Dermatology in Rzeszow, Poland. This source (textual) database contains information about 548 real cases of anonymous patients’ lesions, confirmed by histopathological tests. According to the methodology described by Braun-Falco and Stolz (cf. Braun-Falco et al., 1990), classification of each case in the discussed database relies on the application of the ABCD rule (cf. La Roche-Posay, 2009), in which A (Asymmetry) shows a result of evaluation of lesion’s asymmetry, B - (Border) estimates the character of a rim of the lesion, C - (Color) identifies number of colors (one or more, from 6 allowed) present in the lesion, and D - (Diversity of structures) stands for the number of structures (one or more, from 5 allowed). Logical values of descriptive attributes allowed are gathered in Table 1.

Elements of ABCD rule enumerate four main symptoms of an investigated lesion, and at the same time these elements are used to compute the TDS (Total Dermatoscopy Score) parameter (cf. Braun-Falco et al., 1990), using the equation (1):

\[
TDS = 1.3 \times \text{Asymmetry} + 0.1 \times \text{Border} \\
+ 0.5 \times \sum \text{Color} + 0.5 \times \sum \text{Diversity}
\] (1)

According to TDS value, the analyzed lesion could be assigned to one of four accepted categories (classes), namely: Benign nevus, Blue nevus, Suspicious nevus or Melanoma malignant (see Table 2.).

Distribution of the investigated lesion categories in the discussed database is shown in Table 3.

Recently, the synthesis of discussed images is based on latest results of the mutual research with Kansas University (cf. Alvares et al., 2003; Grzymała-Busse and Hippe, 2005), differentiating the role of a particular color and structure in the diagnosing process, allowing to determine the value of a new total dermatoscopy score parameter, called New_TDS:

\[
\text{New\_TDS} = (0.8 \times \text{Asymmetry}) + (0.11 \times \text{Border}) \\
+ (0.5 \times \text{C\_White}) + (0.8 \times \text{C\_Blue}) \\
+ (0.5 \times \text{C\_DarkBrown}) + (0.6 \times \text{C\_LightBrown}) \\
+ (0.5 \times \text{C\_Black}) + (0.5 \times \text{C\_Red})
\] (2)
Table 1: 15-component textual data-vector

<table>
<thead>
<tr>
<th>Descriptive attribute</th>
<th>Logical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt;\text{Asymmetry}&gt;)</td>
<td>(&lt;\text{symmetric lesion}&gt;)</td>
</tr>
<tr>
<td></td>
<td>(&lt;\text{one-axial asymmetry lesion}&gt;)</td>
</tr>
<tr>
<td></td>
<td>(&lt;\text{two-axial asymmetry lesion}&gt;)</td>
</tr>
<tr>
<td>(&lt;\text{Border}&gt;)</td>
<td>Even numerical value oscillating between 0 and 8</td>
</tr>
<tr>
<td>(&lt;\text{Color}&gt;)</td>
<td>present / absent</td>
</tr>
<tr>
<td>- black</td>
<td>present / absent</td>
</tr>
<tr>
<td>- blue</td>
<td>present / absent</td>
</tr>
<tr>
<td>- dark-brown</td>
<td>present / absent</td>
</tr>
<tr>
<td>- light-brown</td>
<td>present / absent</td>
</tr>
<tr>
<td>- red</td>
<td>present / absent</td>
</tr>
<tr>
<td>- white</td>
<td>present / absent</td>
</tr>
<tr>
<td>(&lt;\text{Diversity of structures}&gt;)</td>
<td>present / absent</td>
</tr>
<tr>
<td>- branched streaks</td>
<td>present / absent</td>
</tr>
<tr>
<td>- pigment dots</td>
<td>present / absent</td>
</tr>
<tr>
<td>- pigment globules</td>
<td>present / absent</td>
</tr>
<tr>
<td>- pigment network</td>
<td>present / absent</td>
</tr>
<tr>
<td>- structureless area</td>
<td>present / absent</td>
</tr>
<tr>
<td>TDS (Total Dermatoscopy Score)</td>
<td>Numerical value computed according to the equation (1)</td>
</tr>
</tbody>
</table>

Lesion’s category
\(<\text{benign nevus}>\)
\(<\text{blue nevus}>\)
\(<\text{suspicious nevus}>\)
\(<\text{malignant melanoma}>\)

Table 2: Classification of melanocytic skin lesions in dependence of TDS-value

<table>
<thead>
<tr>
<th>TDS value</th>
<th>Lesion’s category</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS &lt; 4.76 and lack of color blue</td>
<td>Benign nevus</td>
</tr>
<tr>
<td>TDS &lt; 4.76 and color blue is present</td>
<td>Blue nevus</td>
</tr>
<tr>
<td>4.76 &lt;= TDS &lt; 5.45</td>
<td>Suspicious nevus</td>
</tr>
<tr>
<td>TDS &gt;= 5.45</td>
<td>Melanoma malignant</td>
</tr>
</tbody>
</table>
Table 3: Distribution of the lesion categories in the database

<table>
<thead>
<tr>
<th>Diagnose</th>
<th>Number of cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign nevus</td>
<td>35</td>
<td>66</td>
</tr>
<tr>
<td>Blue nevus</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Suspicious nevus</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Melanoma malignant</td>
<td>13</td>
<td>24</td>
</tr>
</tbody>
</table>

+ (0.5 * Pigment_Network) + (0.5 * Pigment_Dots)
+ (0.6 * Pigment_Globules) + (0.6 * Branched_Streaks)
+ (0.6 * Structureless_Areas)

3 Methodology of the research

At present, developed algorithms are improved by using hybrid, i.e. vector-raster type approach to synthesis of lesions images. Namely, the usual vector technique is combined with an approach based on the Active Shape Model (cf. Cootes and Taylor, 1992) (further called ASM), and then used to synthesize of lesion’s asymmetry (mapping the value of the $<\text{Asymmetry}>$ attribute). On the other hand raster graphics operations are implemented for mapping the remaining characteristic attributes of lesion’s images, i.e $<\text{Border}>$, $<\text{Color}>$ and $<\text{Diversity of structures}>$. The mapping of those attributes is accomplished by using pre-defined fragments (so called textures) of images of melanocytic lesions in combination with the using of Gaussian filter (cf. Lifshitz and Pizer, 1990). Finally, instead of previously mentioned textual informational database (cf. Hippe, 1999), we use a new database, which contains 212 real digital images of melanocytic lesions and 53 descriptive (textual) data vectors.

4 Synthesis of lesion’s asymmetry

Mapping of lesion’s asymmetry relies first on the use of ASM algorithm (cf. Cootes at al., 1994), and then application of de Casteljau algorithm (cf. Zorin et al., 1996), for the tentative creation of the synthesized images (see Fig. 1).

Active Shape Model is a kind of structural information about the mean shape of a digital image, joined with information about the deviation from the “mean shape”. ASM models can be obtain by statistical analysis of so called point distribution model (cf. Wikipedia, 2009), from set of points labeled onto the learning images, with the required condition, that points (landmarks) of each training images represents a required correspondence (Fig. 2). Every shape $\mathbf{x}$ from the training set is represented as an n-point polygon in images coordinates: $\mathbf{X} = (x_1, y_1, \ldots, x_{n-1}, y_{n-1}, x_n, y_n)^T$ (every point with coordinates $(x_n,y_n)$ for $n$ equal from 1 to 64 was defined manually at intersections of 64-fold symmetry axis with an edge of the lesion image (Fig. 3)). Then, each new shape is obtained
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Figure 1: A sequence of selected operations in process of synthesis of an image

According to the Eq. (3):

\[ X = \Gamma + P_t \ast b \]  \hspace{2cm} (3)

where: \( \Gamma \) is the mean shape of all images from the training set, \( P_t = [u_1, u_2, \ldots u_t] \) includes first \( t \) eigenvectors of the covariance matrix, and \( b = [b_1, b_2, \ldots b_t]^T \) contains shape model parameters for each of the selected eigenvectors. Components of the weight vector \( b_i \) can be fixed within the following region:

\[-s \ast \sqrt{\lambda_i} \geq b_i \leq s \ast \sqrt{\lambda_i} \]  \hspace{2cm} (4)

Here \( \lambda_i \) is a selected eigenvalue, whereas \( s \) is a constant factor, receiving in our research constant value equal to 3.

Figure 2: Selected images from the learning set with marked landmark points
Series of 64 new formed point's, received as a consequence of changing co-
ordinates of mean shape point's (according to eq. (4)) are connected by 64 segment
lines (see Fig. 2).

![Image](image_url)

**Figure 3:** An example image from the training set with marked 64 points

Connecting the consecutive points define the control polygon of the curve. Finally, using algorithm of cutting corners(cf. Wikipedia2, 2009), each segment line is splitted with a fixed ratio $t / (1-t)$. The process should be repeated until arriving at the single point (this is the point of a curve corresponding to the parameter $t$). This process is performed iteratively: a curve created via this method is known as Bezier curve (cf. Manocha and Demmel, 1994). Example of 3 different shapes, obtain according with the discussed methodology, for $<two-axial asymmetry lesion>$ type is presented on Fig. 4.

![Image](image_url)

**Figure 4:** Examples of 3 different shapes, defined with Bezier curves for $<two-axial asymmetry lesion>$

5 **Algorithms of synthesis colors and structures of the lesion’s**

Synthesis of colors and structures of lesion’s should consider multi-argument char-
acter of $<Color>$ and $<Diveristy of structure>$ attributes, capable to create con-
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A considerable number of combinations of these parameters, appearing simultaneously in a given lesion. Structurally:

\[
COLORS \times STRUCTURES = \{ (color, structure) \epsilon \ P( P(COLORS \cup STRUCTURES)) : \ color \epsilon COLORS \land structure \epsilon STRUCTURES \} \tag{5}
\]

where \( P(COLORS) \) means power set of \( COLORS \) set. These calculations lead to the conclusion that the synthesis required a special approach: initially (before generating textures), there is an attempt to find which colors and structures occur simultaneously in a real lesions (cf. Hippe and Piątek, 1999). Basing on these findings, the developed algorithms can be simplified through application of so called basic textures, having two combinations of colors only: images with color blue, appearing separately, and images with colors dark-brown and light-brown. In the next step, for the prepared \( a \ priori \) texture, containing basic color (Fig. 5b) and binary image with previously defined Bezier surface (Fig. 5a), the logical product is computed, applying following rules: every pixel of ultimate image (Fig. 5c) with coordinates \((x_i, y_i)\) is designed by means of pixels with coordinate \((x_i, y_i)\) of bitmap, if pixel of image with Bezier surface is white. However, if pixel of vector type graphic is black, then pixel of ultimate image is also black.

![Figure 5: Adding basic color to pre-defined Bezier surface](image)

The remaining (i.e. additional) colors in combination with required structures are defined in additional layers (each of 5 diversity of structures is defined in each of 6 permitted colors). For each additional layer (Fig. 6a) binary images, which are a copy of these texture (but in black and white colors) are then defined; we call them image mask (Fig. 6b).

![Figure 6: Additional layer with dark-brown structureless area (a) and its mask image (b)](image)
The algorithm of adding the additional layers is executed as a two-step process. First, a mask image (Fig. 7a) is placed on top of the primary (basic) texture (Fig. 7c). The white parts of image mask represent the transparent part of the mask, whereas black parts represent the solid part. It should be emphasized, that the type of blending used, causes the black parts of mask will appear on the scene only (Fig. 7d). Then blending modes is switch, and logical sum operation of image with required structure (Fig. 7b) and image from Fig. 7d is applied. The final image is shown on Fig. 7e.

At the end of the discussed process, a special operation is defined for adding an image of healthy skin to encircle the lesion (see Fig. 8).

6 Synthesis of lesion’s border

Algorithm of synthesis of lesion’s <Border> is similar as diagnosing this symptom by medical doctor already described in (cf. Hippe at al., 2006). Presently, the mapping of the border of lesion image is accomplished by means of specific conversion based on low-capacity Gaussian filter (cf. Lifshitz and Pizer, 1990) for the regarded fragments of an image.

7 Program implementation

Developed algorithms of synthesis melanocytic lesion’s asymmetry are implemented in C++ language, combined with the use of MFC (Microsoft Foundation Classes) library (cf. MFC, 2009) and OpenGL graphic library (cf. OGL, 2009). GUI (Graphic User Interface) of the application (at moment in Polish) is presented below on Fig. 9.
8 Summary and conclusion

The new algorithms described here follow a new line to hybrid synthesis of images. It was found, that developed algorithms implemented in the computer program system (ImageSYNTHESIZER) can be easily applied to create very large, multi-category informational database, which can be successfully used not only in teaching of medicine students, but also in job a practice of dermatologists and preferred medical doctors. It seems that synthetic images, generated by means of the developed algorithms, can be successfully used as an alternative source of knowledge in relation to digital medical images.

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