

Matching Noisy Outline Contours Using a Descriptor Reduction Approach

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Abstract. Shape Matching is an important area in computer vision researches. We propose in this paper a method to match two outline shapes. Assuming that shapes are stored in the database using their textual descriptors, an iterative process is used to reduce descriptors. After the reduction process, the textual descriptors can be compared in order to perform the matching process. The Textual smoothing is done by applying transformations and reductions of the textual descriptors of shapes to be matched.

Keywords: Descriptors, matching, smoothing, reduction, Textual descriptors.

1 Introduction

Different representations of shapes have been proposed these last years and used in the recognition process. The most known representations are based onto appearance[1], outline contour [2, 3, 4, 5, 6, 7, 8], aspect-graph[9, 10], set of characteristic outline points [11], medial axis of silhouettes [12, 13], shock graph[14, 15], and shape axis trees (S-A-trees)[16]. A review of shape representation methods may be found in [17, 18]. In [19], authors propose a part-based method for silhouettes representation. Silhouettes are partitioned into parts, junction and disjunction lines. Each element is then geometrically described. The obtained description is written following an XML language noted **XLWDOS** (**XML Language for Writing Descriptors of Outline Shapes**). Since real images are noisy, there XLWDOS descriptors may be very different. This sensitiveness to noise does not facilitate their use in the matching and recognition processes. A notion of multi-scale descriptors of silhouettes is introduced and applied to match silhouettes. A Gaussian convolution of silhouettes is done in order to smooth outline shapes and eliminate noise depending on the value of the Gaussian scale. Also, noisy XLWDOS descriptors of silhouettes may be matched using a reduction technique that eliminates noisy elements from the descriptors. This paper is structured as follows:

We present in the second section an overview of the part-based method for describing outline shapes. In the third section we show the sensitiveness to noise of XLWDOS descriptors. In the fourth section, we explain our strategy based on the matching of XLWDOS descriptors using the reduction technique. The proposed method is validated using real images and the obtained results are presented and discussed in the fifth section.

2 Silhouettes Description

Concavity points for which direction of outer contour changes following top-bottom-top or bottom-top-bottom are considered as partition points (see figure 1.a). A silhouette is partitioned at these points onto parts, junction and disjunction lines: either, two parts or more are joined with a third part through a junction line, or a part is joined with two parts or more through a disjunction line. This process applied to the left silhouette in figure 1. produces seven parts, two junction lines and one disjunction line. The silhouette descriptor is the grouping of descriptors of its elements. A part is defined by its two boundaries (left and right) which begin at the highest left point and terminate at their lowest points (see figure 1.b). Using the inflection points, these boundaries are segmented into a set of primitives (line, convex and concave contours) and described by the parameters: type (line, convex or concave curve), degree of concavity or convexity, angle of inclination and length. Junction and disjunction lines are decomposed onto segments. Each segment is described with three parameters: type, the reference numbers of parts where it appertains and its length. Types of segment are: **Junction** if it is common for two parts, **Free-High** if it belongs only to the high part or **Free-Low** if it belongs to the low part. Applying this description to write the descriptor of part P_2 of the shape in the left of figure 1, we obtain:

$$P_2 \rightarrow \langle P_2 \rangle \langle L \rangle cv 6\% 56 76 \langle /L \rangle \langle R \rangle cv 16\% 107 77 \langle /R \rangle \langle /P_2 \rangle$$

This descriptor is read as follow: The left boundary of part 2 is composed by a convex contour with 0.06 as degree of convexity, 56° of inclination and 76 pixels as length. The right boundary is composed by a convex contour with 0.16 as degree of convexity, 107° of inclination and 77 pixels as length.

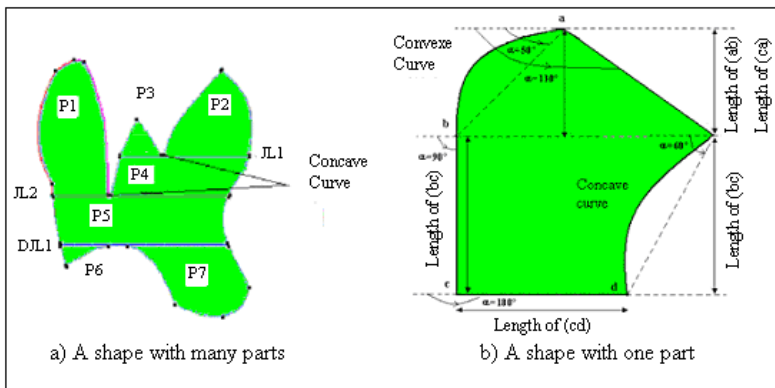


Fig. 1. Example of a silhouette, concave points, and parts

The notion of **composed part** is defined as a set of two (or more) parts joined to another part using a junction (or a disjunction) line and written as follows:

Composed Part $\rightarrow \langle CP \rangle P_1 P_2 \dots P_{n-1} \langle J \rangle$ Junction line $\langle J \rangle P_n \langle CP \rangle / \langle CP \rangle P_1 \langle D \rangle$
 Disjunction line $\langle D \rangle P_2 P_3 \dots P_n \langle CP \rangle$

Recursively, a composed part is considered as a part and may constitute (with other elements) other composed part. There are three composed parts in the XLWDOS descriptor of the left silhouette in figure 1:

- $\langle CP \rangle P_2 P_3 \langle J \rangle JL_1 \langle J \rangle P_4 \langle CP \rangle$
- $\langle CP \rangle P_1 \langle CP \rangle P_2 P_3 \langle J \rangle JL_1 \langle J \rangle P_4 \langle CP \rangle \langle J \rangle JL_2 \langle J \rangle P_5 \langle CP \rangle$
- $\langle CP \rangle \langle CP \rangle P_1 \langle CP \rangle P_2 P_3 \langle J \rangle JL_1 \langle J \rangle P_4 \langle CP \rangle \langle J \rangle JL_2 \langle J \rangle P_5 \langle CP \rangle \langle D \rangle DJL1 \langle D \rangle P_5 P_6 \langle CP \rangle$.

To write descriptors of silhouettes we use the following syntax:

Silhouette $\rightarrow \langle DXLWDOS \rangle \langle Name \rangle Objectname \langle /Name \rangle$ Composed Part $\langle /DXLWDOS \rangle$
 (**DXLWDOS** means description according to **XLWDOS** description).

Finally, the descriptor of the silhouette in figure 1 is:

```

<DXLWDOS><Name>Silhouette 1</Name>
<CP><CP><P1><L>r 32 10 cv 14% 88 102 r 90 10 </L><R> r 165 8 cv 6% 100
120</R></P1>
<CP><P2><L>cv 6% 56 76</L><R>cv 16% 107 77</R></P2>
<P3><L> r 64 32</L><R>r 123 32</R></P3> <J>j P3 P4 36 w P4 2 j P2 P4 75</J>
<P4><L> r 76 34 </L><R> r 63 34</R></P4><CP> <J>h P1 1 j P1 P5 48 w P5 2 j P4 P5
103 h P4 1</J>
<P5><L> r 98 41</L><R>cc 11% 88 41</R></P5><CP> <D>j P5 P6 42 h P5 17 j P5 P7
87 w P7 1</D>
<P6><L> r 105 19 </L><R>cc 6% 27 19</R></P6>
<P7><L>cc 10% 127 53 cv 7% 165 11</L><R> r 115 38 cv 17% 48 26</R></P7></CP>
</DXLWDOS>
    
```

3 Sensitiveness to Noise of XLWDOS Descriptors

XLWDOS descriptors are sensitive to noise which may produce additional parts, junction and disjunction lines. Noise may then change the global structure of XLWDOS descriptor, but in other cases it changes only the geometric description of its elements. Figure 2.b illustrates an example where noise produces in addition, two parts, one junction line, two other parts, and one disjunction line relatively to the shape 2.a. Also, noise may correspond to concave points that the change of position creates new parts and lines. The silhouette of figure 2.d illustrates an example where a concavity point change of position produces additional parts and lines relatively to the shape 2.c. Finally, the XLWDOS descriptors are robust to noise when it changes only the geometric description of contours; it's the case of the silhouette 2.e. Depending on the direction of computation of the XLWDOS descriptor; noise may change the global structure of XLWDOS descriptors.

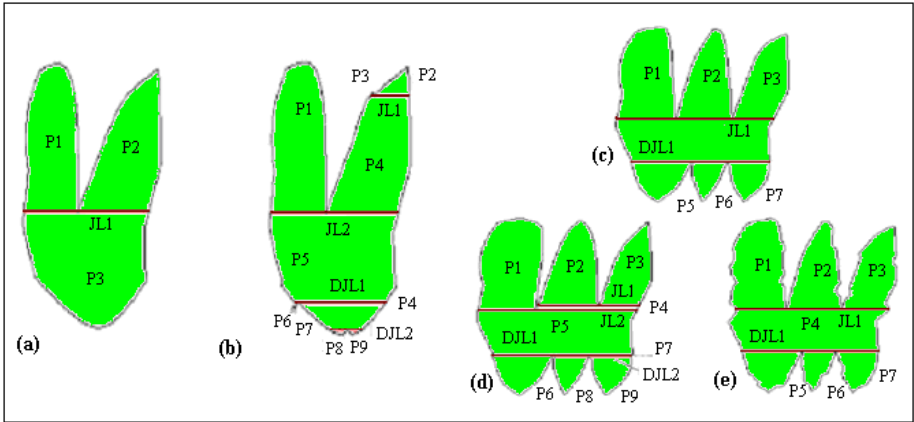


Fig. 2. Noisy outline shapes

4 Matching Descriptors of Silhouettes

A. Matching descriptors in multi scale space

As it is described above, XLWDOS descriptors are sensitive to noise. Therefore, it is necessary to take into account this noise in the matching process. In a previous work we have developed a method comparing silhouettes at different scales [20] to eliminate noise from outline shape applying a convolution with a Gaussian filter. We obtain for each value of σ a smoothed outline shape. We define the notion of multi-scale XLWDOS descriptors as the set of descriptors computed using these smoothed outline shapes obtained at different scales (values of σ) from the initial outline shape. More the value of σ increases, more the XLWDOS descriptor contains less elements whose number becomes steady from a certain value of σ . [20]. In this present work, we will see that it is possible to found same results with textual transformation of descriptors without Gaussian Smoothing.

B. Reduction method

We define a noisy part, as a part whose length is 1, 2, 3 or n pixels. Each noisy part will be marked in the written descriptor using the two tags $\langle N \rangle$ $\langle /N \rangle$. For example, the XML structure of XLWDOS descriptors of silhouette 2.a and 2.b are:

```
<DXLWDOS><Name>Silhouette2a</Name>
  <CP><P1></P1><P2></P2><J></J><P3></P3></CP></DXLWDOS>
<DXLWDOS><Name>Silhouette2b</Name>
  <CP><CP><P1></P1><CP><P2></P2><N><P3></P3></N><J></J><P4></
P4></CP><J></J><P5></P5></CP>
  <D></D><N><P6></P6></N><CP><P7></P7><D></D><N><P8></P8></N
><N><P9></P9></N></CP></CP>
</DXLWDOS>
```

These two descriptors cannot be matched because they have different structures. Therefore, the problem is to verify if we can reduce the two descriptors in order to

maintain in their XML structures only their main parts. For this, we propose a reduction method that takes into account all possible positions of noisy parts in the XML structure.

Also, the XML structure of XLWDOS descriptors of silhouettes 2.c and 2.d are:

```

<DXLWDOS><Name>Silhouette2c</Name>
  <CP><CP><P1></P1><P2></P2><P3></P3><J></J><P4></P4></C
P>
<D></D><P5></P5><P6></P6><P7></P7></C>
</DXLWDOS>
<DXLWDOS><Name>Silhouette2d</Name>
<CP><CP><P1></P1><CP><P2></P2><P3></>
<J></J><N><P4></P4></N></CP>
  <J></J><P5></P5></CP>
  <D></D><P6></P6><CP><N><P7></P7></N>
<D></D><P8></P8><P9></P9></CP></CP>
</DXLWDOS>
  
```

The principle of our reduction method is as follows:

When the size of a part (Psi) is negligible in relation with sizes of main parts, the (Psi) will be considered as noisy and will be suppressed from the initial descriptor. The noisy part size is, therefore, less than a fixed threshold.

Let be:

$\langle CP \rangle Ps_1 Ps_2 \dots Ps(i-1) Psi Ps(i+1) \dots Psn Ji Pm \langle /CP \rangle$, a composed part according to XLWDOS Descriptor.

The same descriptor, after removing the noisy part (Psi), becomes:

```

<CP>Ps1 Ps2 ... P's(i-1) Ps(i+1)... Psn J'i Pm</CP>.
  
```

P's(i-1) is generated from Ps(i-1) where the description of left boundary of P's(i-1) is the same than the left boundary of Ps(i-1). The right boundary of P's(i-1), is the right boundary of Ps(i-1) for which we add the noisy part (Psi) and the segments of separating lines adjacent to (Psi).

The separating line descriptor will also be modified according to the new part obtained after the reduction process. Indeed all segments that were adjacent to (Psi), will be assigned to the new part P's(i-1).

The graphic illustration of this technique is given in Figure 3.

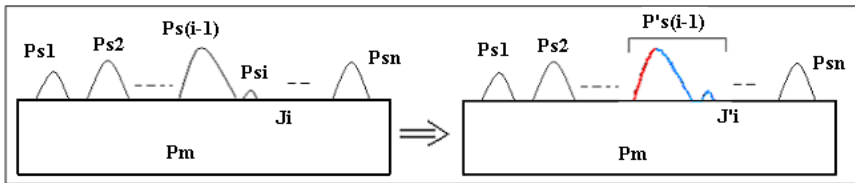


Fig. 3. Elimination of a noisy part in the textual description

This is a recursive process; it is applied to remove all noisy parts from the descriptor while parts sizes are less than the fixed threshold and while the two descriptors to be matched remain different during the reduction process.

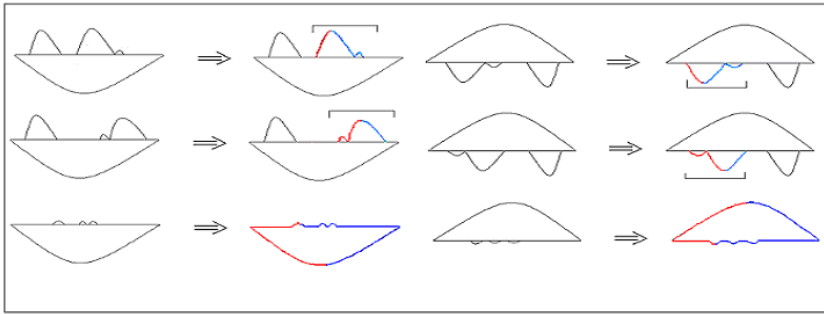


Fig. 4. Examples of descriptors reduction

For example, using the reduction method, the XML structure of XLWDOS descriptor of silhouette 2.d becomes:

```
<DXLWDOS><Name>Silhouette2d</Name>
<CP><CP><P1></P1> <P'2></P'2><P'3></P'3><J></J><P5></P5></CP>
<D></D><P6></P6> <P'8></P'8><P'9></P'9></CP>
</DXLWDOS>
```

Now, the XML structure of both descriptors (Silhouette2c and Silhouette2d) are similar, therefore the matching of their elements may be done.

Other examples of transformations are given by graphic illustrations in Figure 4.

5 Experimentation

In figure 5, we show two images of the same object (cup). There are parts and junction lines in the descriptor of the first image which could not be matched with other parts and lines in the descriptor of the second image.

After applying a convolution with a Gaussian filter for the two outline shapes, smoothed outlines shapes are obtained and the obtained XLWDOS descriptors of both two images become similar.

The matching problem has also been solved using our reduction method. The approach is been applied for the two noisy XLWDOS descriptors and gave same results. Indeed, the first noisy descriptor computed (of the first image) has the following structure:

```
<DXLWDOS><Name>Cup1</Name>
<CP><CP><CP><CP><N><P1></P1></N><N>
<P2></P2></N><J></J><P3></P3></CP><P4>
<P4><J></J><P5></P5>
</CP><N><P6></P6></N><J></J><P7></P7></CP>
<D></D><CP><N><P8></P8></N><D></D>
<N><P10></P10></N><N><P11></P11></N></CP><N><
P9></P9></N></CP>
</DXLWDOS>
```

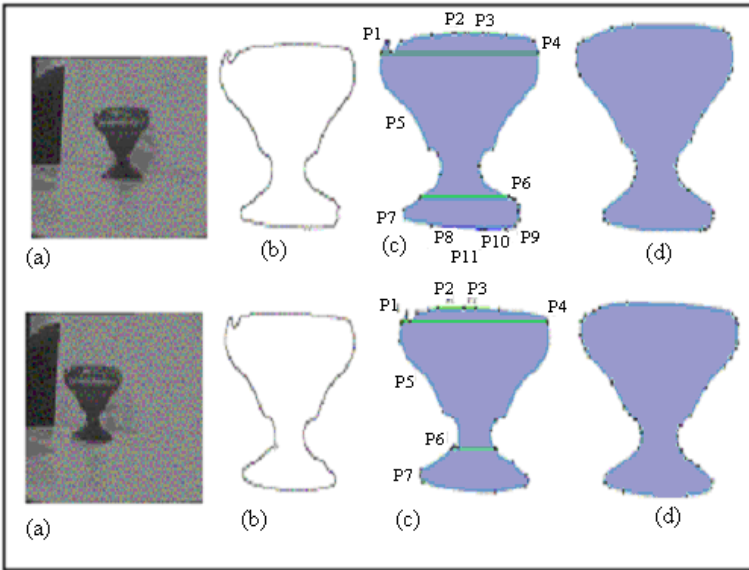


Fig. 5. For each image (a), the extracted outline shape of a cup (b), the result of applying XLWDOS description for outline shape (c) and the smoothed outline shape with $\sigma=10$ (d)

This descriptor is reduced as follows:

```

<DXLWDOS><Name>Cup1</Name>
<CP><P1∪P2∪P3></P1∪P2∪P3>
  <P4></P4><J></J><P5∪P6∪P7∪P8∪P10∪P11∪P9></P5∪P6∪P7∪P8∪P10∪
  11∪P9> </CP>
</DXLWDOS>
  
```

where: $\langle P1 \cup P2 \cup P3 \rangle \langle /P1 \cup P2 \cup P3 \rangle$ designates the part obtained as the union of the three parts P1, P2 and P3. Therefore the obtained descriptor may be written:

```

<DXLWDOS><Name>Cup1</Name>
  <CP><P'1></P'1><P4></P4><J></J><P'5></P'5></CP> </DXLWDOS>
  
```

The second noisy descriptor computed (of the second image) has the following structure:

```

<DXLWDOS><Name>Cup2</Name>
<CP><CP>
  <CP><N><P1></P1></N><N><P2></P2></N><J></J><P3></P3></CP>
<P4></P4><J></J><P5></P5></CP>
<N><P6></P6></N><J></J><P7></P7></CP>
</DXLWDOS>
  
```

This descriptor is reduced as follows:

```
<DXLWDOS><Name>Cup2</Name>
<CP><P1∪P2∪P3></P1∪P2∪P3>
<P4></P4><J></J><P5∪P6∪P7></P5∪P6∪P7></CP>
</DXLWDOS>
```

Therefore the obtained descriptor may be written:

```
<DXLWDOS><Name>Cup2</Name>
<CP><P''1></P''1><P4></P4><J></J><P''5></P''5> </CP>
</DXLWDOS>
```

Now both the two images descriptors (of cup1 and cup2) can be matched and their similarity is obtained by comparing the elementary contours of the obtained parts.

Two other examples of experiments are given in Figure 6, the same process is applied and similar results are obtained; the descriptors of smoothed shapes become similar.

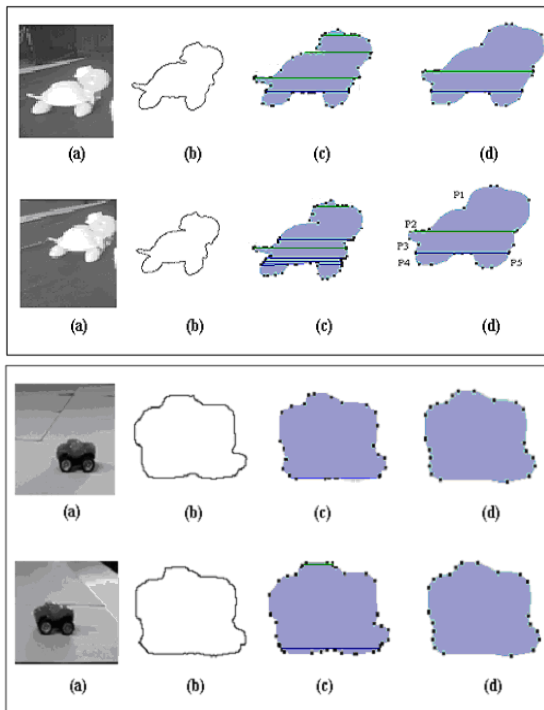


Fig. 6. For each image (a), the extracted outline shape (b), the result of applying XLWDOS description for outline shape (c) and the smoothed outline shape with $\sigma=10$ (d)

6 Conclusion

In this paper we proposed an efficient method for silhouettes matching despite the presence of noise. We have seen the possibility to match noisy silhouettes using their descriptors.

The proposed solution was illustrated by the writing of XLWDOS descriptors including the information of noisy parts. A reduction method has been developed in order to reduce their XML structures and let only main non-noisy parts.

The conducted experiments show the usefulness of the proposed approach and demonstrate the possibility to use XLWDOS descriptors for real images applications.

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