# A NOVEL SHAPE DESCRIPTOR BASED ON EXTREME CURVATURE SCALE SPACE MAP APPROACH FOR EFFICIENT SHAPE SIMILARITY RETRIEVAL

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***Abstract*— The main drawbacks of Curvature Scale Space (CSS) matching are due to the problem of shallow and deep concavities on the shape. To solve this problem, in this paper we present a novel shape descriptor based on Extreme Curvature Scale Space (ECSS) map approach. Unlike the CSS map of shape which results from zeros crossings values of the curvature, the ECSS map is created by tracking the position of extreme curvature points. Similarly to CSS descriptor, our proposed one is based on the maxima of the obtained ECSS map. It is robust with respect to noise, scale and orientation changes of the shape. Several experiments have been conducted on a SQUID database. The obtained results prove the efficiency of the proposed shape descriptor when is compared to the CSS one, especially in the case of shallow or deep concavities.**

*Keywords— CSS map, ECSS map, Shallow and Deep Concavities. Shape similarity.*

## I. Introduction

The curvature of a curve has salient perceptual characteristics [1] and has proven to be useful for shape recognition [2]. Mokhtarian and Mackworth [3] have developed the Curvature Scale Space (CSS) technique which was one of the features selected to describe objects in the MPEG-7 standard [4], the maxima of CSS image are used to represent two-dimensional (2-D) shapes at different levels of resolution. This representation has proven to be robust under noise, scaling, orientation and translation changes.

The drawbacks of CSS matching are mainly due to the problem of shallow and deep concavities on the shape [5][6]. It can be shown that the shallow and deep concavities may create the same large contours on the CSS image. Therefore, a shallow concavity may be matched with a deep one during the CSS matching. Consequently, dissimilar shapes can be described as similar shapes because of this failure. As an example, the two shapes in Fig. 1(a)-(d) are different shapes, however their CSS image in Fig. 1(b)-(e) are quite similar.

This problem was previously analyzed in [7] by adding more information to the CSS image maxima. However, the proposed strategies depend on some empirical parameters that need to be fine tuned and raise the computational costs significantly [8]. In [9], the authors propose to use Concavity-Convexity Scale Space (CCSS) representation;

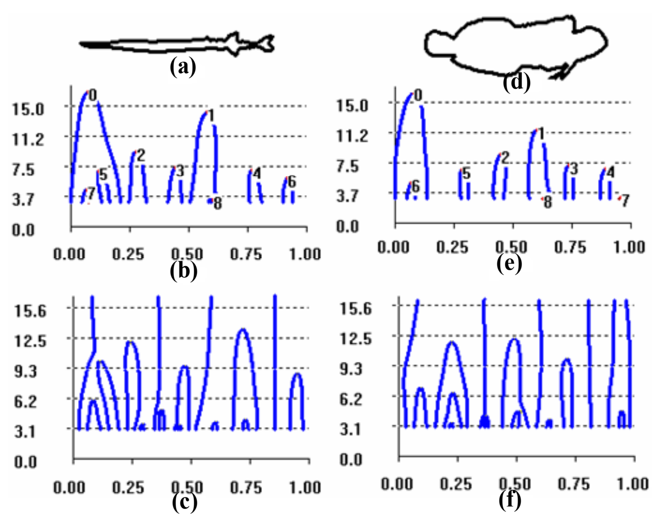


Figure 1. (a) Shape with a shallow concavity on the boundary; (b) its CSS image (c) its ECSS image (d) shape with a deep concavity on the boundary; (e) its CSS image; (f) its ECSS image.

this later has been embedded on a new system to support identification of military vessels. The proposed CCSS was only used to deal with shapes having shallow concavities. An other representation based on CSS is also proposed by Kopf et al in [10] named Extended Curvature Scale Space (ECSS). The standard CSS technique is applied to original shape to characterize only concave parts, and applied CSS technique to the dual shape to characterize only convex parts. From the above works, the matching problem between shapes with shallow and deep concavities was not yet solved.

To solve the problem of the shallow and deep concavities, in this paper, a novel shape descriptor is proposed. It is based on Extreme Curvature Scale Space ECSS representation which is not a novel approach [11].

In the ECSS approach, the ECSS map is created by tracking the position of extreme curvature points in a shape boundary filtered by low-pass Gaussian filters of variable widths. The result of this process is a several contours map. In the proposed shape descriptor, the maxima of these contours are used for shape description. It is robust with respect to noise, scale and orientation changes of the objects and it can distinguish between shallow and deep concavities.

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The remainder of the paper is organized as follows. Section 2 presents a new shape descriptor and its properties. In Section 3, several retrieval examples are conducted to compare between CSS and our descriptor especially in the case of shallow or deep concavities. Finally conclusion remarks are given in section 4.

## II. Extreme Curvature Scale Space Based Shape Descriptor

From a mathematical point of view, a planar continuous curve can be parameterised according to its arc-length. Let $f(u) = \left\langle (x(u), y(u)) \middle| u \in [0,1] \right\rangle$ be the parametric representation for a given curve of shape, where u is the normalised curvilinear abscise. And let $\langle g(u,\sigma)/\sigma \geq 0 \rangle$ be set of Gaussians

Where, for a given σ, g(u,σ) is given as follows: $g(u, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-u^2}{2\sigma^2}}$ .The set of the smoothed curves $\langle f(u,\sigma)/\sigma \geq 0 \rangle$ is a multi scale representation of the curve of shape f(u). Those smoothed curves are obtained by the convolution of f(u) with the set of Gaussians $g(u, \sigma)$ for different values of σ.

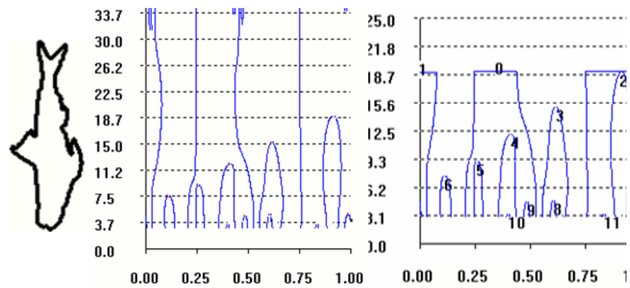
A set of a multi scale curvature $K(u,\sigma)$ that corresponds to the set of curve of shape $\langle f(u,\sigma)/\sigma \geq 0 \rangle$ can be defined as follows:

$$K(u,\sigma) = \frac{x_t(u,\sigma)y_{tt}(u,\sigma) - x_{tt}(u,\sigma)y_t(u,\sigma)}{\left(x_t^2(u,\sigma) + y_t^2(u,\sigma)\right)^{3/2}}$$

Where $x_t$, $y_t$ et $x_{tt}$ ,$y_{tt}$ are respectively the first and second derivatives of x and y with respect to t.

Let $P = \{P_{i(\sigma)}\}_{i=1}^{N}$ be the set of minima that is the set of points such as $K(u,\sigma)$ =0 (set of inflection points). If we assume that the curvature $K(u,\sigma)$ is continuous between two consecutive minima $P_{i(\sigma)}$ and $P_{(i+1)(\sigma)}$ , Rolle's theorem applies, and indeed, there is always an extremum $m_{i(\sigma)}$ (minimum or maximum) of $K(u,\sigma)$ located at point $P_{mi(\sigma)}$ between these points $P_{i(\sigma)}$ and $P_{(i+1)(\sigma)}$ , it could have several minima and maxima between two curvature zero-crossing points. As a result, a set of extremum curvature points can be extracted from each smoothed contour shape description in multi scale representation. The result of this process can be represented as a binary image called the ECSS image (extreme Curvature Scale Space image) of the curve (see fig. 2).

It is clear, as the scale σ increases, the infection points become less, and therefore, at the highest scale (σ>>0), the boundary is smooth and there is no inflection points, but




(a) (b) (c)

Figure 2. (a) A fish shape; (b) the evolution of extreme curvature points of shape in (u,.σ) plane; (c) the ECSS image of shape.

our proposed process continue to extract some extreme curvature points. Hence, the main problem is the condition for terminating the processes, i.e. for which value of σ we must stop our algorithm. To solve this problem, we propose to take into account only the extreme curvature points between each pair of successive zero-curvature points. So, our algorithm for determination of the extreme curvature points stops when the curvature zero-crossing points disappear (the number of curvature zero-crossing points will be zero).

The final ECSS descriptors contour are composed of all maximum curvature points from the ECSS image. Hence, the peaks (i.e. the maxima) are then extracted out and sorted. In the case of incomplete contour map, we take into account both its branches. Finally, our ECSS descriptors based on the ECSS image, which are like CSS descriptors based on the CSS image, are composed of all maximum points $E_p(u_p, \sigma, m_p)$ in the ECSS image, where $u_p$ is the normalized arc length, σ is the width of the Gaussian kernel and $m_p$ is the curvature at which the Ep is obtained. As seen in Fig. 2 (c), there are 8 complete contour map and 3 incomplete contour map. Each incomplete map is described by both its branches, thus there are 14 peaks of the corresponding ECSS descriptors for the shape in fig.2 (a). Finally, the shape in fig.2 (a) is presented as:

ECSS = {(0.246 , 19.1, 1.645) ; (0.075, 19.0, 2.14) ; (0.44, 19.0, 0.688) ; (0.75, 19.0, 0.66) ; (0.91, 18.9, 0.875) ; (0.619, 15.10, 1.98) ; (0.41, 12.10, 1.80) ; (0.26, 9.10 ,1.64) ; (0.11, 7.50, 1.88) ; (0.99,4.80,1.35) ; (0.61,4.70,1.21) ; (0.49, 4.60, 1.09) ; (0.40 , 3.20, 0.98) ; (0.84, 3.20, 0.73)}

Small contours of the ECSS image are related to noise or small ripples of the curve. As a result, small maxima are not included in this representation. A problem with the proposed ECSS image is that the peaks for a given outline are based on the curvature function which is computed starting from an arbitrary point on the outline. If the starting point is changed, then there is a cyclic shift along the normalised arc length of the peaks in the ECSS image. In order to solve this problem, when a similarity measure is computed, all possible shifts need to be investigated.

The proposed descriptor makes two changes to curvature scale space method: it substitutes the use of contour extrema for curvature zero crossings and it adds

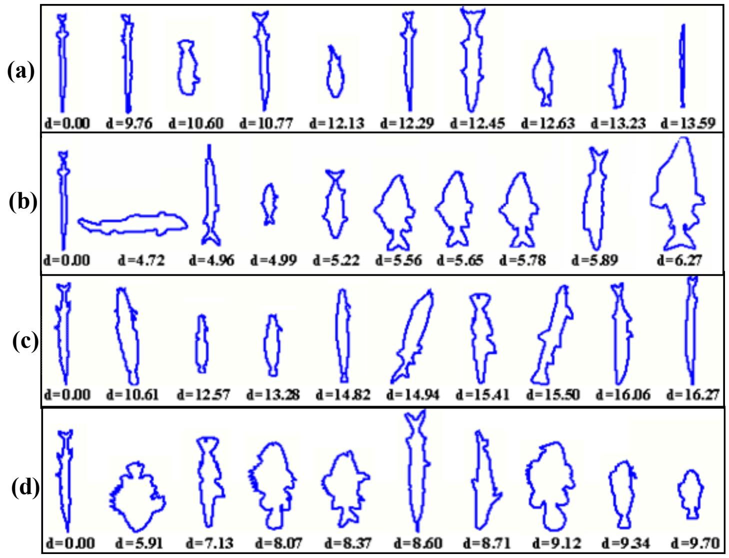



Figure 3.Result of K-NN search of a shape query with shallow concavity for the same queries using both ECSS and CSS. (a) and (c) using ECSS descriptor. (b) and (d) using CSS descriptor.

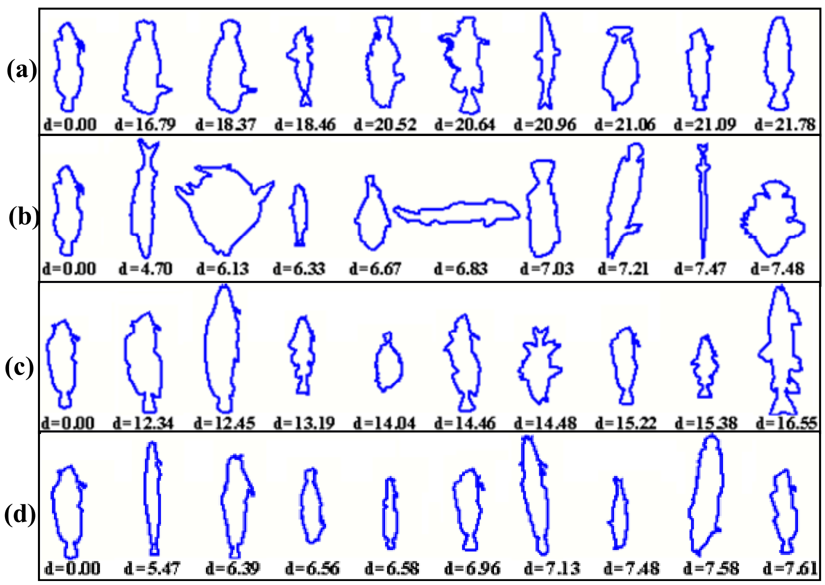



Figure 4. Result of K-NN search of a shape query with deep concavity for the same queries using both ECSS and CSS. (a) and (c) using ECSS descriptor. (b) and (d) using CSS descriptor.

the value of the curvature in each extreme as an additional feature on each of the matched points. One of the great benefits to integrate the curvature characteristic for descriptor ECSS is to distinguish between shape with shallow and with deep concavities. Fig.1(c)-(f) show the ECSS map respectively of the two shapes in Fig. 1(a)-(d). Unlike the CSS image, we deduce that two ECSS images are different.

## III. EXPERIMENTAL RESULTS

We have developed in visual C++ a system for the indexing and retrieving of shapes using both CSS and ECSS descriptors. We used the SQUID database [12], which contains 1099 images of marine creatures described by their shapes. The system retrieves similar shapes to the user query from the database in decreasing order of similarity using the K-nearest neighbour algorithm. Figure 3 and Figure 4 show four example shapes with shallow and deep concavities which are used as query in our experiments. The first teen similar shapes to the query are displayed from left to right. From a subjective point of view, the obtained results show the superiority of our proposed shape descriptor over the CSS one.

For shallow shape query, the returned results by using CSS descriptor present some shapes having deep concavities, for example the returned shape in fig. 3(b), and fig. 3(d).

However, in the obtained results by applying our proposed descriptor to the same shallow shape query presented in fig. 3(a) and fig. 3(c), we remark that there is no shape with deep concavities.

For deep shape query, the returned results by using CSS descriptor present some shapes having shallow concavities, for example the returned shape in fig. 4(b), and fig. 4(d).

However, in the obtained results by applying our proposed descriptor to the same deep shape query presented in fig. 4(a) and fig. 4(c), we remark that there is no shape with shallow concavities.

These experiences prove the efficiency of the proposed shape over the CSS one for both shallow and deep concavities, even by using the same matching algorithm developed for CSS shape descriptor [3].

Note that the similarity measure is usually developed by taking into account the used shape descriptor. We propose in the next work to develop a similarity measure more suitable for our proposed shape descriptor.

## IV. CONCLUSION

To solve the problem of indexing and retrieving shapes with shallow and deep concavities on the shape, in this paper we present a novel shape descriptor based on Extreme Curvature Scale Space (ECSS) map approach. Similarly to CSS descriptor, our descriptor is also robust with respect to noise, scale and orientation changes of the shape. Several experiments have been conducted on a SQUID database. From a subjective point of view, the obtained results prove the efficiency of the proposed shape descriptor when is compared to the CSS one, especially in the case of shallow or deep concavities.

For objective comparison, we propose in the future work to develop a similarity measure which must be will more suitable for our proposed shape descriptor.

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