53. IWK

Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

Faculty of
Mechanical Engineering

PROSPECTS IN MECHANICAL ENGINEERING

8 - 12 September 2008

www.tu-ilmenau.de

TECHNISCHE UNIVERSITÄT
ILMENAU

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=17534

Published by
Impressum

Publisher Herausgeber	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Dr. h. c. Prof. h. c. Peter Scharff
Editor Redaktion	Referat Marketing und Studentische Angelegenheiten Andrea Schneider
	Fakultät für Maschinenbau Univ.-Prof. Dr.-Ing. habil. Peter Kurz, Univ.-Prof. Dr.-Ing. habil. Rainer Grünwald, Univ.-Prof. Dr.-Ing. habil. Prof. h. c. Dr. h. c. mult. Gerd Jäger, Dr.-Ing Beate Schlütter, Dipl.-Ing. Silke Stauche
Editorial Deadline Redaktionsschluss	17. August 2008
Publishing House Verlag	Verlag ISLE, Betriebsstätte des ISLE e.V. Werner-von-Siemens-Str. 16, 98693 Ilmenau

CD-ROM-Version:

Implementation Realisierung	Technische Universität Ilmenau Christian Weigel, Helge Drumm
Production Herstellung	CDA Datenträger Albrechts GmbH, 98529 Suhl/Albrechts

ISBN: 978-3-938843-40-6 (CD-ROM-Version)

Online-Version:

Implementation Realisierung	Universitätsbibliothek Ilmenau ilmedia Postfach 10 05 65 98684 Ilmenau

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=17534

53rd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
08 – 12 September 2008

E. A. Destéfanis, A. Buraschi, G. M. Steiner, L. R. Canali, R. Carelli

Contour segment-based shape descriptor

ABSTRACT

A new descriptor model based on shape contour representation aimed to object recognition in non-structured images is presented. The model uses the second derivative of the contour curve –a rotation invariant representation- for contour representation. A contour segmentation criterion suitable for form description is presented. An adaptation of this descriptor able to operate in scale-space is discussed. Some results are presented and further research work is proposed involving descriptor's use in more complex problems.

Keywords: Object identification, gradients, scale-space.

I. INTRODUCTION

Present work is based on concepts related with the specific field of shape recognition, with the goal of obtaining a robust descriptor to be applied in the more general field of object recognition in non-structured images.

Shape recognition has been dealt with by several authors (Price, 1984; Wolfson, 1990; Liu and Srinath, 1990; Mortensen et al., 2005). In those works the general procedure is to propose methods for planar figures characterization, where correspondence among the test figure is sought and evaluated against a reference model whose contour is completely defined. In some work, the possibility to detect the whole profile or segments within it is discussed.

As this kind of problems share the same requirements: high contrast is needed between image and background, but this condition cannot be taken for granted in the general case.

When dealing with object recognition using their contour within non-structured images, i.e. those where illumination and the textures of background and objects are not controlled, special care must be taken with contour information loss. Poor contrast between objects and background causes serious difficulties in defining object boundaries in this context. This work is oriented to the definition of a descriptor suitable for this environment.

II. PREVIOUS WORK

Regarding shape recognition, recent outstanding papers include (Belongie et al., 2002) describing the Form Context algorithm; Shock-based Indexing method by (Sebastian et al., 2002); and (Mortensen et al., 2005) with their Global Context approach.

The Shock-based Indexing descriptor obtains a detailed description of the shape skeleton and the descriptor is defined over it. Information of figure contour is not used.

The Form Context descriptor is obtained from a compact set of pixels belonging to the object boundary which positions are parameterized and arranged in polar form. Additionally an estimation of initial orientation referred to a given reference point is required, which poses an extra problem to solve.

Vector Chain-based descriptor is usually deemed as too noisy to be used in shape recognition. It is also expensive in terms of machine time and also requires shape orientation evaluation to match the shape and the descriptor.

Basically all methods rely on the object's structure or in the perimeter shape. For a comparison of results using both criteria see (Sebastian et al., 2002).

Object recognition in images, on the other hand, has the identification of objects within non structured images regardless their space orientation and scale. Relevant works in this field are the scale space theory and SIFT keys (Lowe, 1999).

III. CONTRIBUTION

Although existing limitations around frontier descriptors using vector chains, this field keeps being attractive. It is mainly due to that it is generally accepted that contours have an outstanding role in the functioning of biological vision (Hubel and Wiesel) and chain descriptors very closely match contours once noise is eliminated. This initial concept asks for further study to obtain an efficient mechanism to apply directly contour descriptors to recognition.

Another fact contributes to the idea of obtaining such a model based on vector chain use: present processor performance and edge detector algorithms allow experiments with ever denser images in ever shorter times yet obtaining boundaries that are quite representative of the parts that build the objects' shape. This means the boundaries obtained are larger, denser and including ever more pixels.

This paper contribution can be presented as follows:

A local descriptor for object boundaries is proposed as main contribution. It is developed around some concepts related to correlation of chain gradients in boundaries, allowing a novel and robust application of these concepts in object recognition within non-structured images.

Furthermore, a mechanism for identification of breakpoints on the reference image contour is introduced. It is based on premises of information conservation in regions of high curvature, in accordance with the usual criterion of using corner information for image correlation applications.

A procedure for descriptor grouping is also proposed.

IV. GRADIENT CHAINS WITHIN COUNTOUR CURVES.

Given the function corresponding to a contour curve

$$C(s) = (x(s), y(s)) \qquad s \in [0, L] \qquad (1)$$

And assuming it has second derivative, the curvature is as:

$$G(s) = \ddot{x}\dot{y} \ldots - \ddot{y}\dot{x} \ldots / [\ddot{x}^2 + \ddot{y}^2]^{\frac{3}{2}} \qquad (2)$$

Where $\dot{x}$, $\ddot{x}$, $\dot{y}$ and $\ddot{y}$ are the first and second derivative of x*(s)* and y*(s)* with respect to *s* respectively.

In practice only the digitized object contour is available and so (1) and (2) are readily obtained. As G*(s)* is computed using the first and second derivative of the contour function, this means that their values result: (a): the angle of each vector segment and (b): the difference in angles of consecutive vectors in the quantized boundary.

V. GRADIENT DESCRIPTOR

Based on the two concepts of the last paragraph, a descriptor suitable for shape recognition is proposed satisfying:

a) the sequence of points of a curve segment within a contour can be expressed as:

$$C(s) = (x(s), y(s)) \qquad s \in [0, L] \qquad (3)$$

b) the sequence of vectors defined by each point and its predecessor can be written as:

$$V(s) = (v(s)) \qquad (4)$$

being:

$$v(s) = (x(s) - x(s-1)), (y(s) - y(s-1)), \quad s \in [1, L] \quad (5)$$

c) the chain of the differences (gradients) of angles between adjacent vectors is:

$$G(s) = ((\arg(v(s)) - \arg(v(s-1)))), \quad s \in [2, L] \quad (6)$$

This last expression is used as the base of a new shape descriptor.

As it is well known, some problems arise from noise existing in the contour chains and affine descriptors. It is then required to filter the gradient chain. This leads to:

$$G_{lp}(s) = F_{lp} * G(s), \qquad s \in [2, L] \qquad (7)$$

F_{lp} is the low pass filter function. In this case it was built around a mean-value filter and a mask of w_{lp} of ten pixels.

To operate in practical applications with this descriptor for shape recognition, a useful approach is to segment all the gradient chains obtained from the perimeter of a reference shape. This means that from a chain a set of sub-chains is obtained such as:

$$G_{lp}(s) = \{g_{lp}(s_i)\}, \quad i = (1,\ldots, n) \quad y \quad \forall\, s_i \,/\, s_i < s \qquad (8)$$

To obtain such a set of sub-chains of angular gradients from an initial contour chain, certain criteria of segmentation must be used.

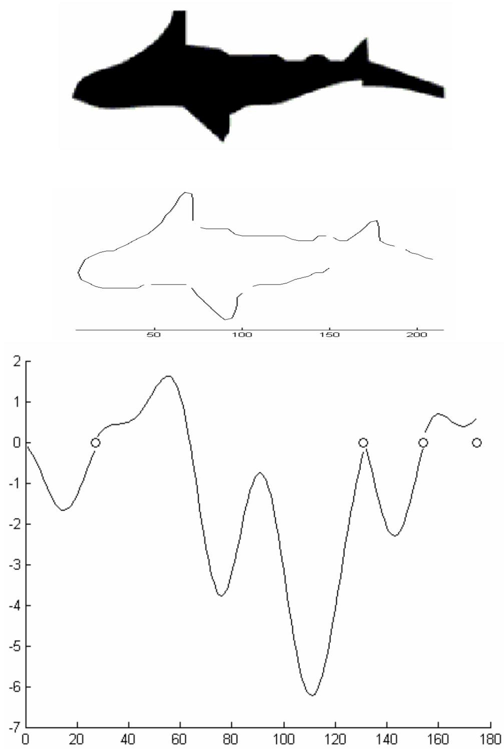

Figure 1: 1) Original shape. -top-, 2) segmented boundary with interruptions in sharp angles -middle- and 3) gradient segment contour representation -low-.

It is important to note that in a given scale of object representation, a sequence of low values in the chain represents a zone of low curvature. In the proposed environment it represents a zone with little information respect to object characterization.

This is the reason why, in a coarse approach, this separation criterion is proposed: to consider that a sequence of small values representing a low gradient does not belong to sub-chains and represent separations among them. This allows searching subsets of chains satisfying the condition that their elements are bounded by a certain limit value θ_{lim} within the original chains. This means:

$G_{seg}(s) = \{g_{seg}(s_i)\}$, $i=(1,\ldots, m)$, $abs(g_{seg}(s_i)) < \theta_{lim}$ (9)

In this way a set of descriptors is obtained from a reference (training) shape. These descriptors are to be matched with shapes obtained from a test image and thus the problem of recognizing a previously apprehended shape within a test image using this descriptor translates into finding coincidences between a set of sub-chains belonging to the shape to be recognized $\{g_{lpref}(s_i)\}$ with $i = (1,\ldots,n_r)$ and the set of sub-chains obtained from the test image $\{g_{lptest}(s_j)\}$; $j = (1,\ldots, n_t)$.

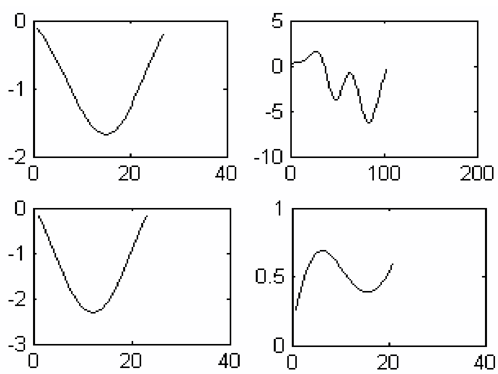

Fig. 2: Segments of gradient chains corresponding to Fig.1. Each segment is the base of a descriptor.

Correspondence between the test object and objects present in the training image is tested comparing each sub-chain from a set with those of the other set and applying one of the well known methods e.g. voting. This means using an algorithm of complexity $O(n^2)$ in the ideal case that all sub-chains were of the same length $n = n_t = n_r$.

In real cases $n_t \neq n_r$, and so chains to be compared have different lengths. This implies that a gradient chain of the reference shape used in a descriptor usually has a different dimension of that obtained in the image of the shape under test. This asks that for determining the possible correlation among them it is required to convolute the smaller with respect to the larger, looking for a segment in which the correlation is so high to decide that they are the same chain.

$$corr = \max \left(corr \left(g_f(s_i), g_t(s_j) \right) \right) \qquad i \neq j \quad (10)$$

This correlation test must de done by travelling around the chains clock- and counterclockwise because a descriptor (gradient chain) obtained when going around clockwise in the reference shape could have been obtained the other way around in the test shape, and so gradient values change sign.

To minimize the time involved in the correlation of the shorter chain into the longer there is a way to seek for zones that have potentially more chances to correlate and thus apply the algorithm on those candidate points. The method simply consists to detect the points of high gradient within the gradient chains and pick as candidates the segments close to those (few) maximum points. In other words: if there are initial gradient values very different in both reference and test chains the chance to have good correlation is very low, and vice versa.

In such a way it is possible to avoid performing the convolution taking every value of the chain as an initial point and instead it can be calculated using those points that have been marked as candidates of being initial points of the longer chain likely to have good correlation with those of the shorter. In such a way an assuming *n* as the mean value of sub-chain size the complexity of the algorithm as applied to real cases can keep within $O(n^2)$.

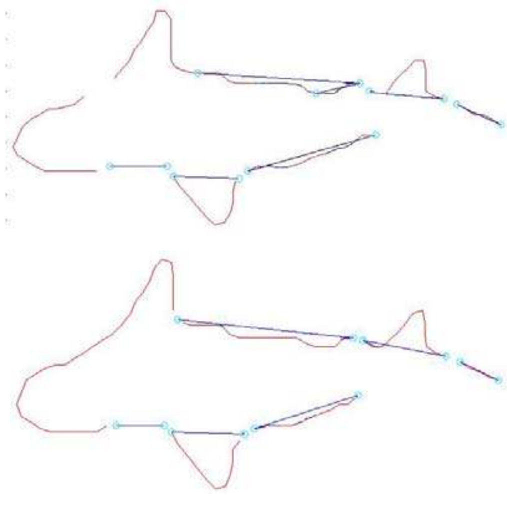

Figure 3: Reference and test shape in the same scale. Breakdown points are observed. In detected similar segments initial and endpoints are marked. They can be used to test the consistency of grouping taking into account the relative positions of the segments thus defined.

VI. CORRELATION AND GROUPING

The correlation of the entire shape is evaluated by means of a voting mechanism, based in the quantity of descriptors that matched well with a certain sub-chain.

As there are chances for a same descriptor to correlate well with more than one sub-chain obtained from the test image, the correct chain is selected using a grouping scheme. Grouping is attained detecting the relative location of each sub-chain in such a way to ensure it corresponds with the sub-chains in the test image as well as with the descriptors pertaining to a certain boundary.

To compare relative positions initial and final pixels of each chain and descriptor are used. These points lend themselves to calculate distances to points of other descriptors to group them as belonging to a certain shape.

To obtain correlation among sub-chains

$$Corr_{sc} = K_c / l_g \qquad (11)$$

can be used, being K_c the obtained value of correlation and l_g the gradient vector length. For the general correlation between the reference shape (as given by descriptors) and the test shape (using sub-chains) the ratio $\sum K_{ci} / S$ can be used, where S is the number of curves where correlation is higher than the defined threshold level and i is each curve's index *1,…i,…n* .

VII. SCALE ESTIMATION

A simple idea to deal with curves having different scales is to transform the chain to different scales within a scale space and to compare with every one of them to figure out if a high correlation exists at least in one of these representations. The method's cost is that of only one scale times the number of levels in the scale space. (Liu and Srinath, 1990) and (Wolfson, 1990) have shown that within a certain range of scales, scale-normalized gradient chains are similar, and so this procedure can be avoided.

It has been assumed until now that chains to be compared are in the same scale. Using normalized gradient chains it is possible to extend the method explained to the more general case in which the reference shape and the test shape are not represented in the same scale. This allows comparing the chains as if they were represented in the same scale.

Normalization coefficients can be used as an indicator of the original chain scale. Normalization can be used within certain interval of scale variation. In the following an alternative method for estimation of the scale of the chain under test is proposed. It may be used where the range of scale value increases, thus widening the uncertainty of the scale value estimated with the normalized method. The reference scale is that of the reference chain, and it is assumed to be known, and so descriptors can be modified into this scale value and thus they can be meaningfully compared.

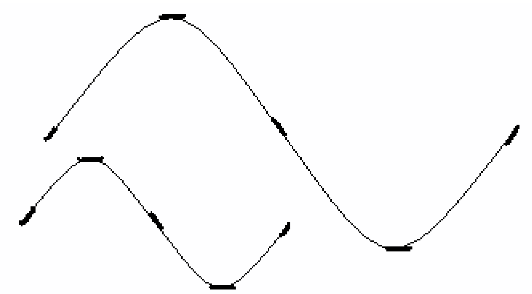

Figure 4: A sequence of slopes can be used to compute the scale value of the contour of the shape.

The problem can be expressed as the estimation of the scale of the test chain in terms of that of the reference chain when describing it. The boundary condition is that the test shape is a candidate for good correlation, that is to say it is assumed that both figures are similar but their scales are different. This is the case depicted in Fig. 1. If the assumed condition holds it is possible to define an interval $\Delta l_{r.}$, where tangents at both ends are computed. Doing the same for all intervals a sequence of slopes γ_i is obtained spaced Δl_r from each other. For the test shape the same sequence of values γ_i is obtained because both shapes are similar but the interval Δl_p is different because of different scale value.

It is possible to match the sequence of values γ_i from the reference shape in the test shape and obtain the set of values Δl_{pi} where sub-index *i* denotes that intervals in the test shape are not equal. If the dispersion of values within Δl_{pi} is less than a threshold value μ, it can be assumed that both curves are the same, but in different scale values. In this case the set of values Δl_{pi} is passed through a low pass filter and the resulting values are averaged to obtain the mean value of the interval Δl_p in the test shape.

The ratio $\Delta l_r / \Delta l_p$ is the ratio of the scales of the curves. This is a sufficient condition for a correlation analysis since that using this value either (a): if the curves are not similar this coefficient would be erroneous, and the comparison of curves with different scale values should lead to an bad correlation (correct situation); or (b): if curves are similar the value of the coefficient is true and the comparison of both curves in the correct scale should yield a good correlation (correct situation).

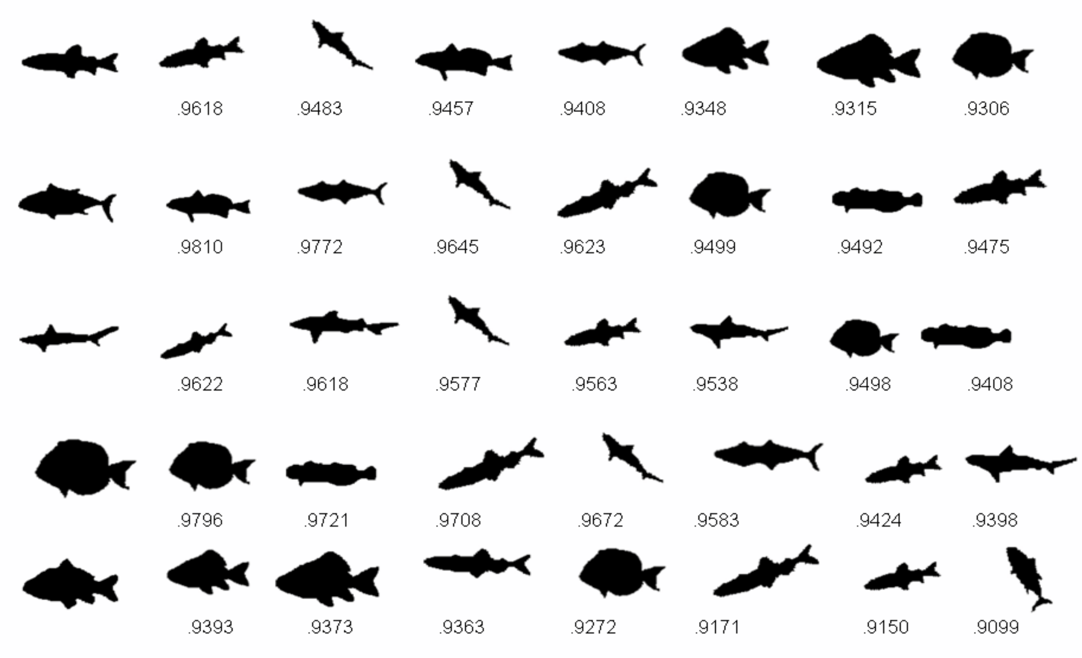

Figure 5: Coefficients obtained for a set of 25 figures. First column depicts the test shape. The figures in the same row show those that were identified as closest to the test image.

This analysis has been made for the original curves obtained in the image space and thus the obtained descriptors are not rotation-invariant.

Another issue to deal with is the estimation of the scale of the test curve using the gradient chain. Gradient chains inherently express the relation of successive slopes in the original curve, and so for each position of the gradient chain a slope can be computed by simple addition of the previous values in the chain, and so the extension of the method presented to gradient chains is clear and simple.

VIII. RESULTS

The method was evaluated using families of binary images shapes of good contour definition. A particularly difficult case is that of Fig. 3 because of the similarity of contour characteristics. The extension of the algorithm to gray-scale figures presenting an unique and well-defined shape was performed using a Sobel operator to obtain the contour curves, and from them gradient was obtained.

IX. ACKNOWLEDGEMENTS

The authors wish to thank the authorities of Córdoba Branch of Universidad Tecnológica Nacional (National Technical University) and the members of Centre for IT Research for their support. This research was carried on with grants from Argentine´s National Agency for Research Promotion within project PICTR 2003-00342 and from the University within project PID 25/E070.

References:

[1] Belongie et al. (2002). Shape Matching and Object recognition Using Shape Contexts. *IEEE Transactions on Pattern Analysis and Machine Intelligence* Vol 24 No 24. Pgs 509 522

[2] Belongie S. and Malik J. (2006). Matching With Shape Contexts. Statistics and Analysis of Shapes, eds. H. Krim and T. Yezzi, Birkhäuser.

[3] Belongie et al. Shape Context: (2000). A new descriptor for shape matching and object recognition, NIPS 2000 Denver, CO, pp. 831-837

[4] Liu H. and Srinath M. (1990). Partial Shape Classification Using Contour Matching in Distance Transformation. *IEEE Transactions on Pattern Analisys and Machine Intelligence*, vol 12 No. 11. 1990.

[5] Lowe D. G. (1999). Object recognition from local scale-invariant features. *In International Conference on Computer Vision*, pages 1150-1157, Corfu, Greece. IEEE Press.

[6] Mortensen E. Deng H. and Shapiro L. A Sift descriptor with global context. (2005) *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05)* - Volume 1. Pp 184 – 190. ISBN ~ ISSN:1063-6919 , 0-7695-2372-2

[7] Price K. E. (1984). Matching Closed Contours. *Proc. IEEE 1984. Workshop Computer Vision.* Pp. 130-134.

[8] Sebastian T., Klein P. and Kimia B. (2002). Shock-based Indexing into Large Shape Databases (2002) ECCV

[9] Sebastian T., Klein P. and Kimia B. (2002). Recognition of Shapes by Editing Their Shock Graphs. *IEEE Trans. Pattern Anal. Mach. Intell*. 26. pp. 550-571 (2002) ECCV

[10] Wiesel, T. N., and Hubel, D. H., (1965). *J. Neurophysiol.*, **28**, 1060–1072

[11] Wolfson H. (1990). On Curve Matching. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 12 No. 5. 1990.

Authors:

Prof. Dr.-Ing. Eduardo Atilio Destéfanis [1]
Mr. Andrés Buraschi [1]
Prof. Guillermo Max Steiner [1]
Prof. Dr.-Ing. Luis Rafael Canali [1]
Prof. Dr.-Ing. Ricardo Oscar Carelli [2]
[1] Universidad Tecnológica Nacional. Facultad Regional Córdoba
Maestro López esq. Cruz Roja Argentina. Ciudad Universitaria
X5016ZAA Córdoba, Argentina
Phone: +54 351 4684006 ext. 144
Fax: +54 351 4681823
E-mail: edestefanis@scdt.frc.utn.edu.ar
[2] Instituto de Automática. Universidad Nacional de San Juan
Av. Libertador San Martín (O) 1109
J5400AHK San Juan. Argentina