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Generating Hierarchical Aspcet Graph Using Silhouettes of Curved Objects.

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abstract

This paper introduces a new approach for computing a hierarchical aspect graph of curved objects. One of the problem of the aspect graph is that the aspect graph is sometimes so complex that much time is required to identify the posture of an object in accordance with it's complexity. We introduce the concepts of the hierarchical description to aspect graph. A viewpoint space are divided into 2 or 3 regions at the top level , and each region is partitioned into more detailed regions in the lower level. In particular , characteristic deformations occur in the neighbourhood of a cusp point as the viewpoint moves. We analyze the division types of the viewpoint space in multiresolution to generate aspect graph from a limited number of viewpoints . Moreover the aspect graph is automatically generated using the algorithm of the minimization criteria. This approach has been implemented and several examples are presented.

1. Introduction

An intelligent vision system should be capable of recognizing arbitrary three-dimensional objects in images obtained from arbitrary viewpoints. This problem has attracted many researchers in computer vision: surveys of three-dimensional object recognition can be found in [7].

Koenderink and van Doorn introduced the notion of aspect graphs for representing an object shape [1]. An aspect is defined as a a qualitatively distinct view of an object as seen from a set of connected viewpoints in the viewpoint space. Every viewpoint in each set gives qualitatively similar projection of the object. In an aspect graph , nodes represent aspects and arcs denote visual events connecting two aspects.

The analysis of curved-surface objects is more complex than for polyhedra. Kergosien cataloged the visual events which can occur for objects bounded by piecewise generic surfaces . Callahan [2] gives some examples of how this catalog of events might be used to derive a partition of the Gaussian sphere. R.Jain proposed partition method of viewpoint space into aspects based on the topologies of contours including occluding contours , as well as a generating algorithm of an aspect graph from the descriptions of the object given in a CAD database. As an object's complexity increases , the aspect number increases as well. Therefore , the method can be applied for only simple objects such as revoluting solids. Many researcher take an interest in the kind of visual events and the boundary viewpoints for curved objects.

As it is difficult to detect the occluding contours from camera images , computer vision systems cannot be made using the approach of aspect graph . We analyze the silhouettes of shapes without occluding contours. The approach of the contour topologies cannot efficiently match the shape and desire its direction and posture because of the enormous volume aspects concerning complex shapes. Leyton developed a set of rules by which process-history can be recovered from smooth natural shapes such as outlines of tumors or islands [5]. Unfortunately we cannot use process grammar to match the shape because of the existence of many descriptions of their outlines. For the purpose of using this description for the identification of an outline , we define the deformable process using scale-space analysis [8] . The processes are compared when the number of the processes is the same. If the two deformable processes are entirely the same , two different viewpoints belong to the same aspect in the process number. As the process number increases , a difference occurs between the two processes and the aspect number increases. That is , the viewpoint space is partitioned into just a few regions in the upper level , and many in lower level.

In section 2 , we discuss the aspects and computations of accidental viewpoints and hierarchical events. The hierachical partition algorithm of an viewpoint space is given in section 3. In particular , the generating algorithm of hierarchical aspect graph which utilizes finite projection images and the matching method is denoted. In section 4 , we apply the algorithm to several sample data sets from camera images.

2. Overview of the aspect analysis

First , we observe curved objects from some viewpoints , and detect the outline of the orthographic projections . The angle signal derived from a viewpoint (η,ζ) in cartesian coordinate is denoted by $\theta_{\eta,\zeta}(l)$. And $\theta_{\eta,\zeta}(l)$ is smoothed by convolution with a Gaussian filter G(t , l) , where $\phi_{\eta,\zeta}(l,t)=\theta_{\eta,\zeta}(l)*G(t,l)$. We then compute zero-crossing contours of a scale-space image . A one-dimensional signal is smoothed by convolution with a Gaussian filter and the zeros of the second derivative are

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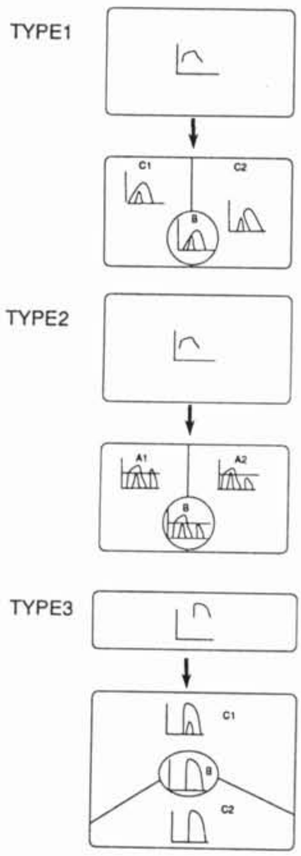

Fig.1 Hierarchical events

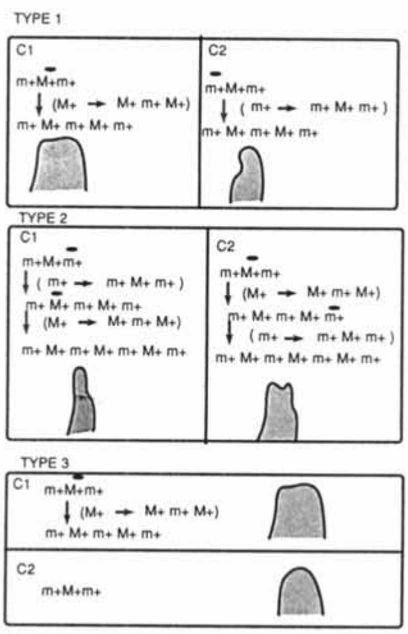

Fig.2 Relation between hierarchical events and deformable processes.

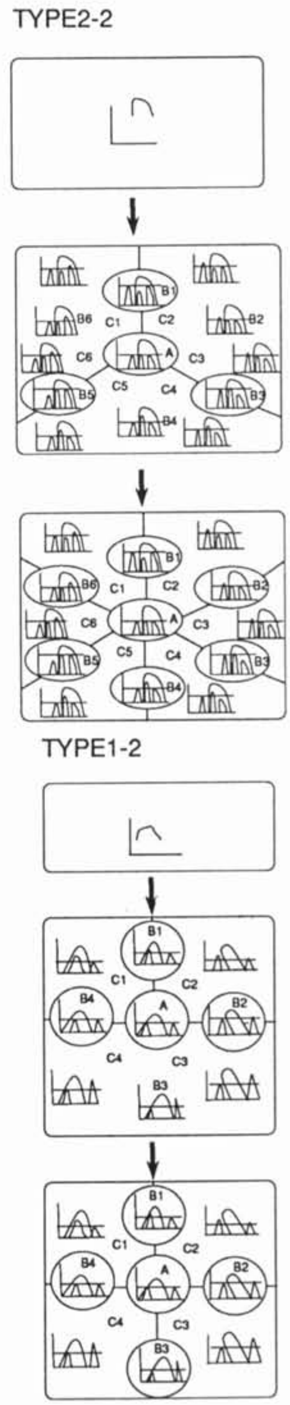

Fig.3 The hierarchical partition of an viewpoint space.

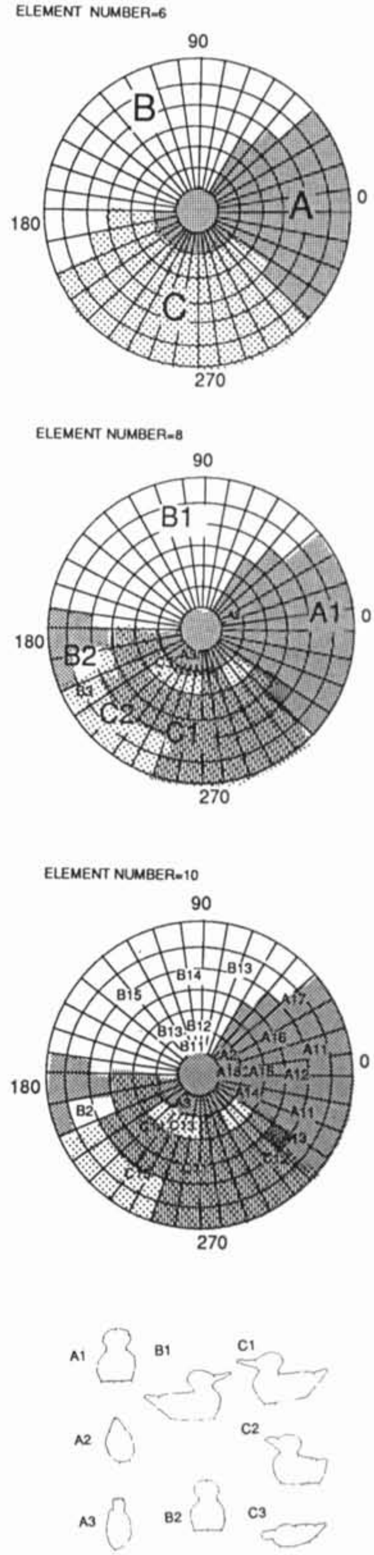

Fig.4 Hierachical partitions of a viewpoint space for the duck.

localized and followed as the size of the filter increases. This procedure creates a plot of the zero contours in the x-σ plane , where σ measures the size of the Gaussian filter. Zero-crossing contours are never created as the scale increases. We interpret the zero-crossing contours into as deformable process. That is , zero-crossing contours are searched for in the scale-space images from the upper level. If the zero-crossing contour appears , the outline deforms in one step. The deformable process is described using four curvature elements , which are M+ , m+ , m- , M-. M and m mean maximum and minimum of curvature , and the positive and negative means the sign of curvature.

We generate a hierarchical aspect graph from 45 orthographic projections obtained from a limited number of viewpoints . Therefore we must understand all the aspect changes and the analyze the aspects and the boundaries between aspects as described in the following.

2.1 Hierarchical Events

Every viewpoint in the viewpoint space can be classified into two different types : a stable viewpoint or an accidental viewpoint. For stable viewpoints , there exists an open neighborhood of viewpoints that gives the same aspect of the object. In partitioning viewpoint space into aspects , we call an event the boundary between each aspects. Each visual event type can be characterized by alterations in the feature configurations . As the process numbers increase , an aspect is partitioned into more fine aspects. The partition of the viewpoint space alternates accidentally in an deformable process number . We call hierarchical event the boundary between each aspect , which is differ in the process number , when an aspect is partioned into only a few aspects. For the purpose of generating the hierarchical aspect graph automatically from images of the finite observed viewpoints and scales , we must analyze the hieachical and visual events.

There are a finite numbers of different hierarchical event. The hierarchical events depend on the difference of zero-crossing contour topology of scale-space images . The hierarchical event occurs , when the following things occur in scale-space images.

Type 1.A zero-crossing contour comes in contact with another contour.

Type 2.The singularity of two zero-crossing contours is at the same height.

Type 3.A zero-crossing contour disappear.

Figure 1 shows three types of the hierarchical events. accidental viewpoint is based on the deformable process. The arrows in the figure indicate the direction of the scale's decreasing. The square frames show a viewpoint space .

Type 1 illustrates that a zero-crossing contour comes into contact with another contour in a scale-space image. Since the topology of the zero-crossing contours are the same in the first frame of Fig.1 , the viewpoint space belongs to an aspect. But , in the next deformable process , a zero-crossing contour comes into contact with another contour , and the difference occurs. C1 and C2 are two stable views , and B is the accidental view. A zero-crossing contour contact with another zero-crossing contour accidentaly. The situation B is the boundary of the two aspects C1 and C2 and the event.

Type 2 illustrates the difference of the the singularities height. C1 and C2 are two stable views , and B is the accidental view. One zero-crossing contour is higher than another zero-crossing contour in A1 , but is lower than the another zero-crossing contour in A2. That is , A1 and A2 differ in the order of deformation. B happens to deform in two places at once.

Type 3 demonstrates that zero-crossing contour disappears in a scale-space image. If the outline is a circle , it will never deform . As the contour is smooth , the contours don't deform without reaching the comparable process number. C1 and C2 are two stable views , and B is the accidental view. The zero-crossing contour disappears in the viewpoint B.

Fig.2 shows outlines and deformable processes corresponding to hierarchical events :Fig.1. If type 1 and 2 of the event happen at the same time , then the two boundary lines dividing a viewing space intersect such as in Figure 3. The point shows the intersect point of the two boundaries. We propose the generating method of a hierarchical aspect graph from limitness viewpoints and resolutions using hierarchical visual events in the following section.

We analyze aspect changes in the neighborhood of cusp points. This is important in the case of describing an aspect such as the contour topology which includes occluding contours. The appearance of occluding contours have three prototypes [9]:lips , beaks and swallows . In these cases , there exists a differntial discontinuity point in $\frac{\partial}{\partial l}\theta(l)$ or $\frac{\partial^2}{\partial l^2}\theta(l)$. By convolving $\theta(l)$ gaussian , a uniqueness deformable process occurs in this discontinuity point. Fig.6 shows aspect changes in the appearance of an occluding contour. The vertical axis in the figure indicates the deformable process of curvature elements , and the horizontal axis indicates the sequence of curvature elements. If the deformable process of A and B appear , there exists C in the boundary of A and B. Their aspect changings form the subset of the hierarchical events.

3. Generating Hierarchical Aspect Graphs

In this paper , we propose the hierarchical partition method of a viewing space . A viewpoint space partitioned by aspects is called a viewing map. Our algorithm for aspect graph generation can be outlined as the following steps .

1.We observe an object in 45 viewpoints and detect the outline of the orthographic projection , and then translate the derived contour into the angle description $\theta(l)$.

2.The gaussian filtering , which σ is 2.0 , 1.2 , 0.8 , 0.2 , is convolved in the angle signal $\theta(l)$.

3. Zero-crossing contours is searched in an scale-space images from the top level. We translate zero-crossing contours into the deformable processes. If the deformable process cannot be determined because of a limited number of resolutions examined , record all deformable processes capable of being derived from observed images.

4.We select the least process in the derivable deformable processes without inconsistency.

In the case of generating from an aspect graph from limited viewpoints and resolutions , there occasionaly exists some additional possibilities of aspect graph . For generating a hierarhical aspect graph , we calculate the minimum number of processes amongst the possible deformation processes from an observed image. We make this selection without violating the requirements necessary to satisfy the differencial geometrical continuities and the continuities of local events and the hierarchical events. The proposed aspect graph is reliable because it is restricted from viewpoint and resolution.

4. Experiments

We observe a duck from 45 viewpoints and genrate an aspect graph from the observed images. We convolved each $\theta(l)$ the gaussian of which being $\sigma = 0.2$ 0.8 1.2 2.0. In the top level , the viewing space was partitioned into three regions :A , B , C when the process number is 3 , and region B was divided into three regions : B1 , B2 and B3 in the next step and these regions were partitioned into more pieces as well . The set of connected viewpoint A is related with B by the event : type1. Moreover the hierarchical event connect B with B1 and B2.

Fig.5 illustrates the matching method. First , we convolve $\theta(l)$ the gaussian $G(t,l)$, which is $\sigma = 3.0$ filter , we translate the signal $\phi(t,l)$ into the deformable process of curvature elements . The process number was used as the index , it is found to be A of the viewpoint. Next , we examined the filter which was approximately coefficient about $\sigma = 2.0$, and we searched the node connected with the bifurcation of A by the hierarchical event. As a result , the viewpoint was included by the sets of viewpoints :B . Finally it was found that the pasture was $(30,0)$ in cartesian coordinate.

5. Conclusions

The aspect is defined as the deformable process of a outline for curved objects in this article. The visual hierarchical events is examined and partition changes of a viewpoint space in multiresolution analysis is found . We have suggested the algorithm generating hierarchical aspect graph from a limited number of viewpoints and resolution. Objects and their directions are efficiently matched using the aspect graph.

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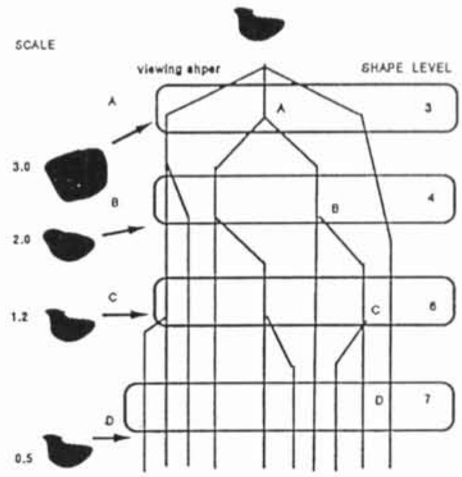

Fig.5 Hierachical aspect graph for the duck.

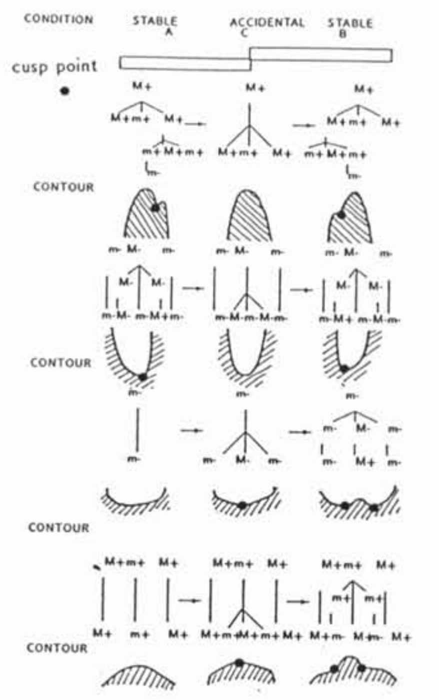

Fig.6 Multiresolution analysis on the cusp points.