Over Some Open 2D/3D Shape Features Extraction and Matching Problems

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MOTIVATION

The amount of digital images increased enormously over the last few years in Internet, satellite, medical, and environmental imaging.

Thus the problem for efficient image database management and quick, automatic, image retrieval is emerging as an active area of research that attracts the attention of mathematicians, computer scientists and engineers.

On the other hand, there is a lack of efficient image retrieval tools on the software market.
It makes the problem promising and attractive for the software developing corporations and agencies working in medical, satellite and/or geo imaging.

Image Database Querying

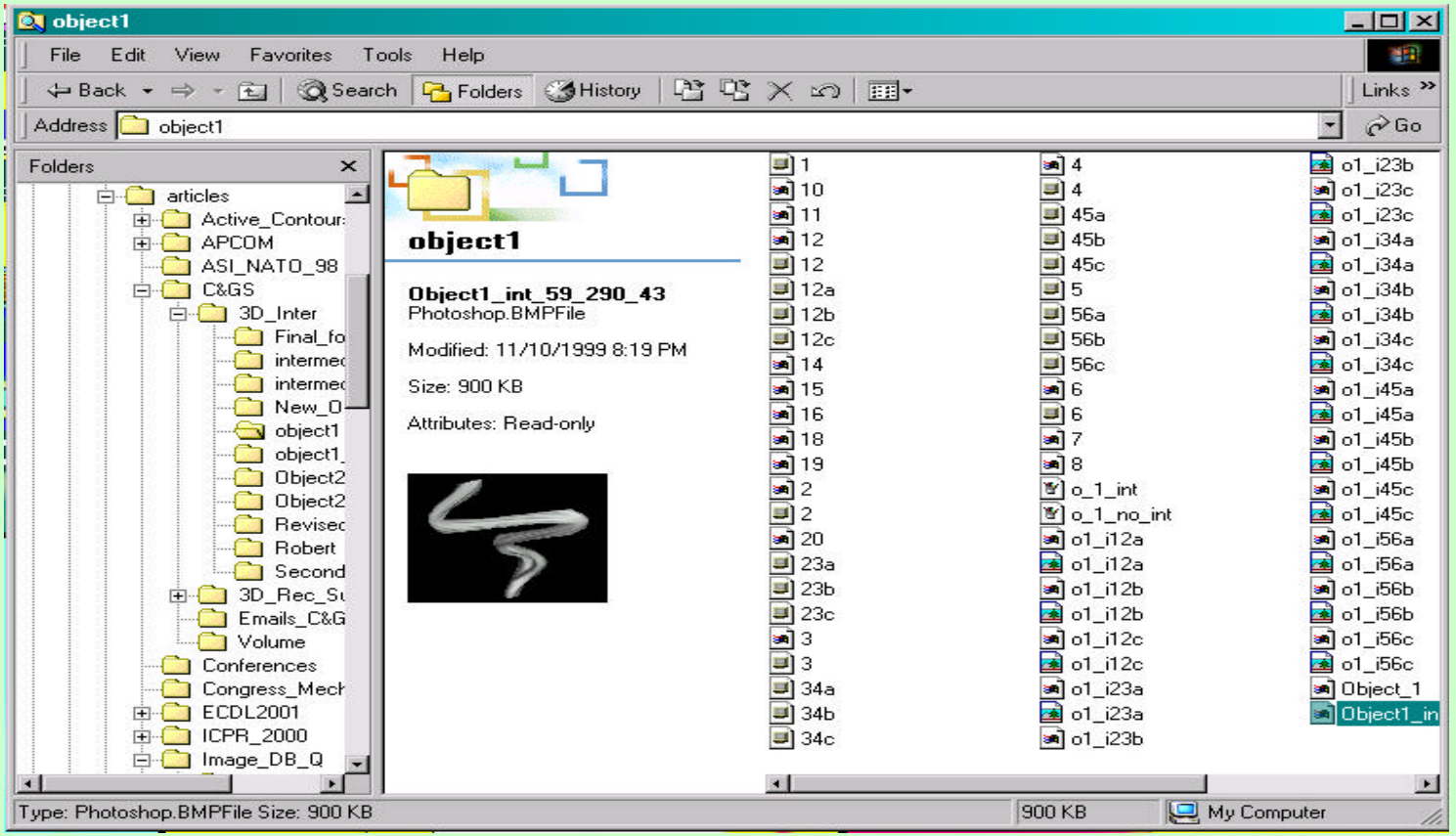


Figure 1. Windows Explorer for browsing images.

VERY BRIEF INTRODUCTION

- **Text-based search**
  - Conventional text-matching techniques
  - Tedious, labor-intensive to prepare text descriptions of images
- **Content-based search**
  - Requires features derived from image content
  - Many features can be automatically extracted
  - Similarity based on feature vectors

Images

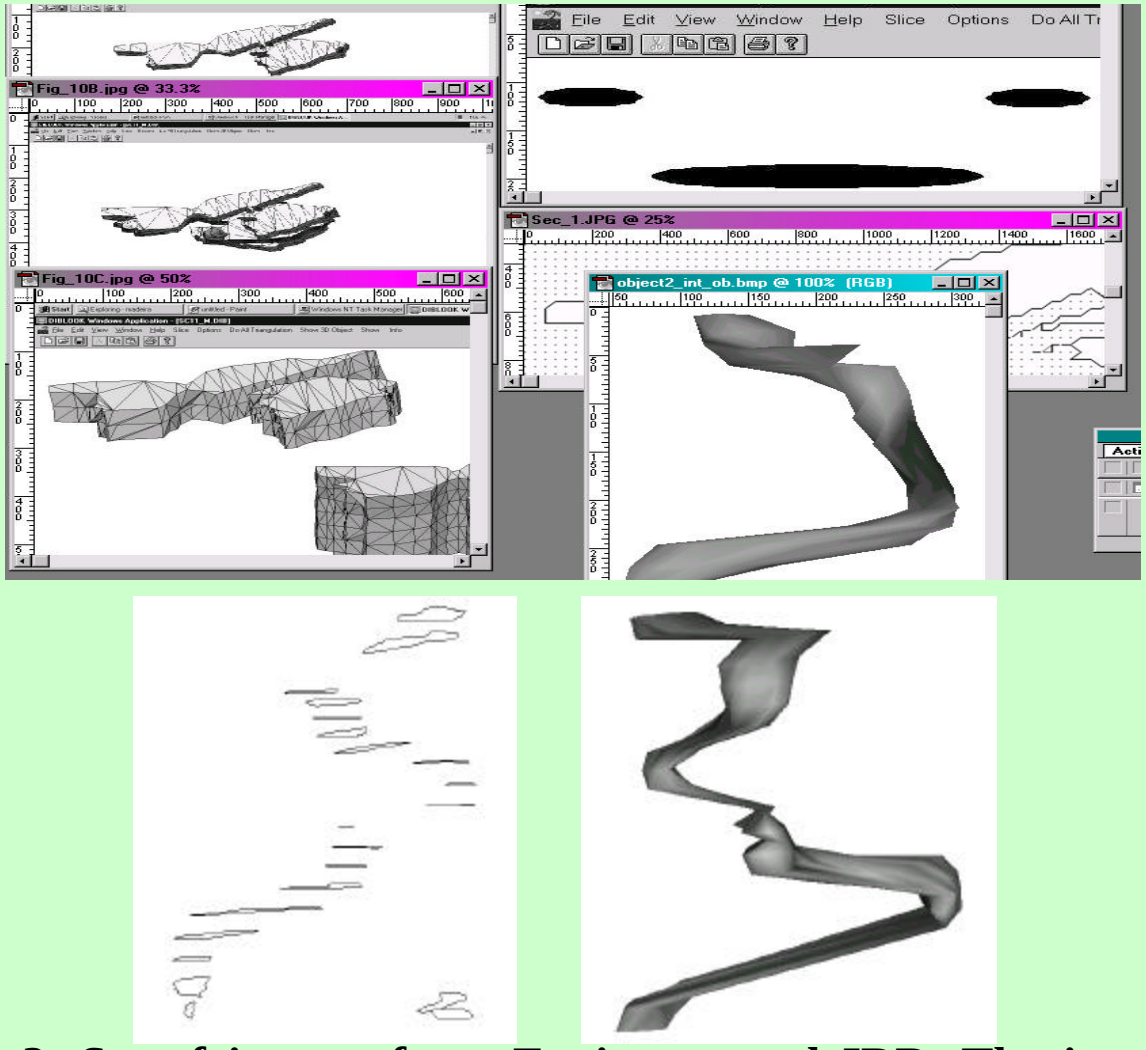


Figure 2. Set of images from Environmental IDB. The images contain 2D sections and 3D modeled subsurface objects.

Applications

- **Air and satellite imagery, GIS;**
- **Biomedical; Biological Imaging;**
- **Chemical; Agricultural Imagery**

-The CBIR is a challenging topic of current research.

The use of extracted image features to rapidly locate a desired image from a large and dynamic collection is widely recognized as an area of active research (Lisani 2001, Yang 2002)

CONTENT BASED IMAGE RETRIEVAL

A CBIR system must be capable of:

- **Image segmentation into distinct regions (Long 1999, Zamora 2001, Yang 2002);**
- **Feature Extraction, Classification (Long 2001);**
- **Indexing by features, (Antani 2003, Chan 2003);**
- **Image retrieval by matching (Latecki 2001, Lee 2003).**

REQUIREMENTS:

1. **To retrieve images in real time;**
2. **To retrieve small amount of images;**
3. **To use as little as possible prior information.**

IMAGE DATABASE MANAGEMENT AND QUERYING

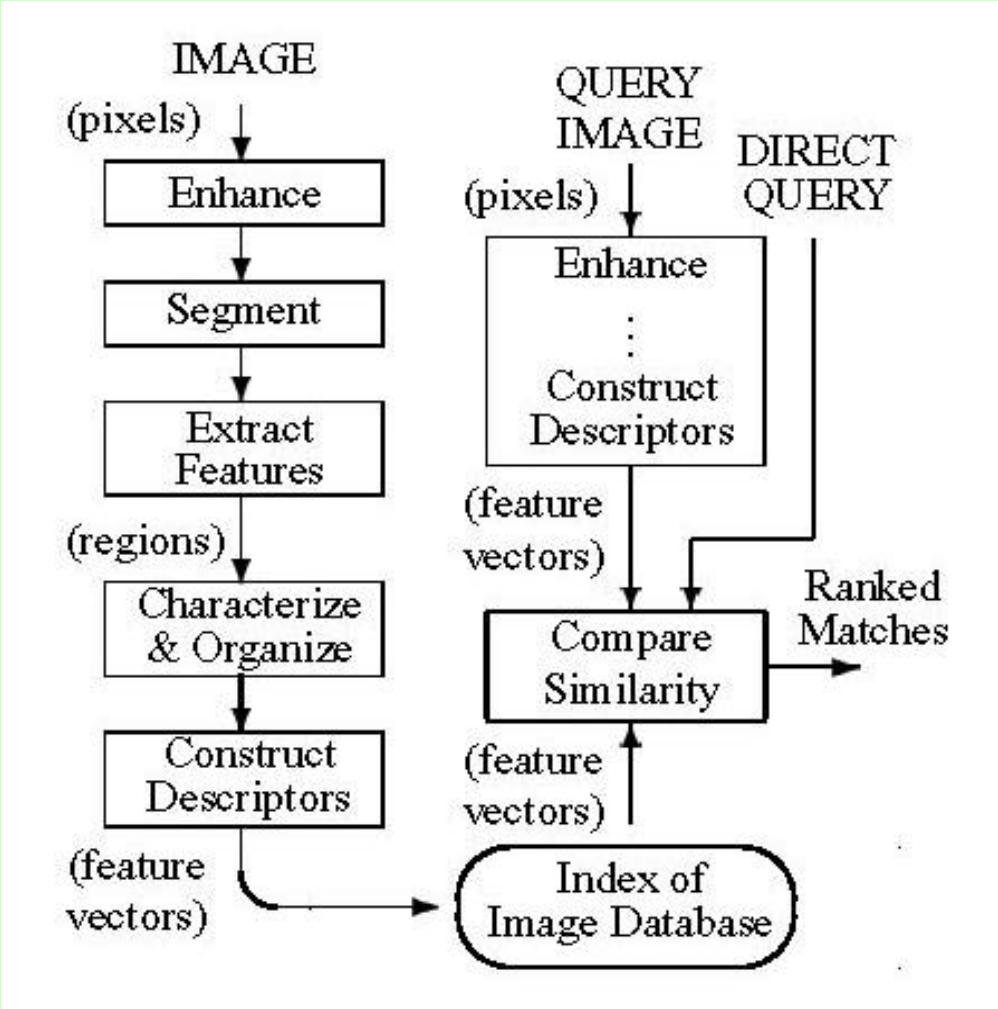


Image DataBase Construction and Querying

IMAGE SEGMENTATION 2D/3D

Definition: A central problem, called *segmentation*, is to distinguish objects from background.

Different types of segmentation by using:

texture, color, shape.

Approaches used:

Texture segmentation can be formulated as a constrained combinatorial optimization problem. Hoffmann, et al. (1996), have employed Gabor wavelet scale space representation and a sparse dissimilarity matrix. The primary disadvantage is its high dimensionality.

IMAGE SEGMENTATION 2D/3D

Shape Segmentation:

Meyer (2000) uses morphological hierarchical segmentation based on families of increasing flooding of a gradient image.

A watershed transform, used by D'Omellas, obtains the edges of the image regions without splitting the color channels.

The main disadvantage of the above methods is over-segmentation, which produces many irrelevant regions.

Another set of approaches, is based on **active models and PDE**, Chan (2003), Vase (2002) and Xu (1998) have emerged in the last decade.

I propose a new shape segmentation approach based on the Heat DE.

Heat Differential Equation to Image Segmentation- **THE 2D CASE**

$$\frac{\partial C}{\partial t} = PkN$$

$$\frac{\vec{N}(p)}{\|\vec{N}(p)\|} = \frac{1}{\sqrt{x_p^2 + y_p^2}}\langle -y_p(p), x_p(p)\rangle$$

Where C is the evolving contour analogous to temperature, t is time, k is the heat of diffusivity, which is analogous to curvature and N is the inward normal vector and P is the penalty function.

The curve C is parameterized by $t \in [0, \infty)$ and $p \in [0, 2\pi]$, where t is time and p is the space between each inward normal vector, $\vec{N}$, on the curve, C.

The image is first transformed to the domain of [-1,1] x [-1,1].

If t is fixed the curve C is parameterized by

$$r(p) = r(t, p) = X(p)i + Y(p)j$$

$$k(p) = \frac{|r_p(p) \times r_{pp}(p)|}{|r_p(p)|^3}$$

The Algorithm for the 2D case

Employing central differences to approximate the 1st and 2nd derivative:

$$\frac{dx}{dp} \approx \frac{x(p+h) - x(p-h)}{2h}$$

$$\frac{d^2x}{dp^2} \approx \frac{x(p+2h) - 2x(p) + x(p-2h)}{2h}$$

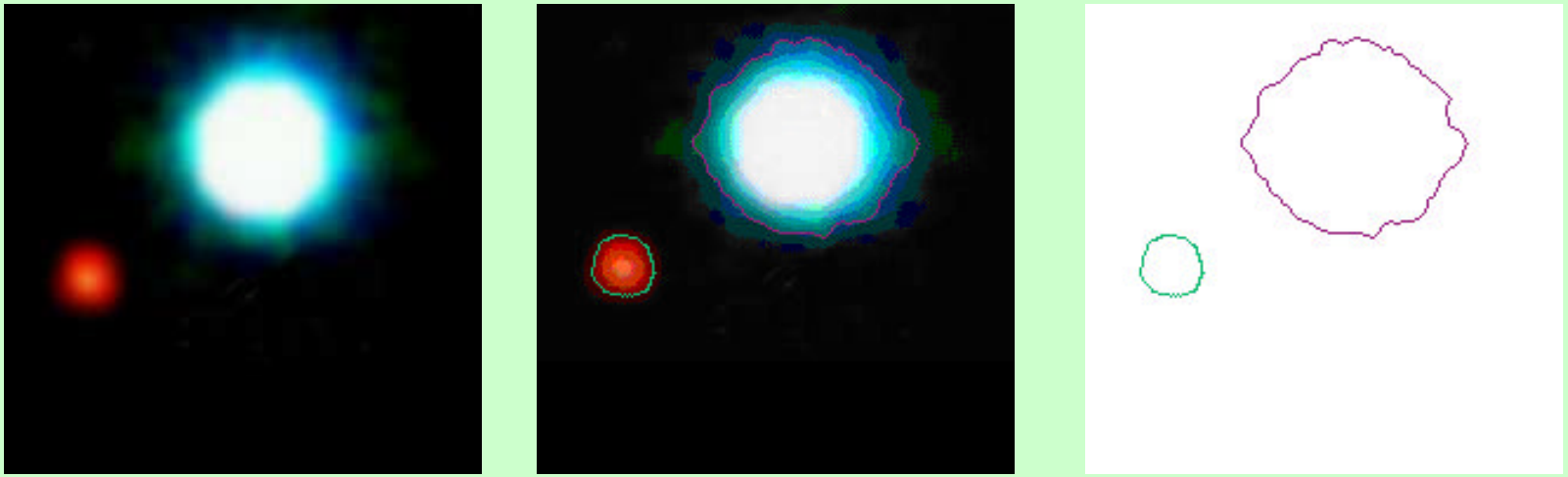
We transform the HDE to the following algorithm:

$$r(t+\delta, p) \approx r(t,p) + \delta P k(t) \vec{N}(t,p)$$

$$r_i^{j+1} = r_i^j + d_i^j k_i^j \vec{N}_i^j P_i^j$$

Where $i=1,\ldots,n$ space index that shows the number of arc segments (normal vectors) on the curve,
and $j=1,2,3,\ldots$, is the family iteration index over time.

COLOR IMAGE SEGMENTATION

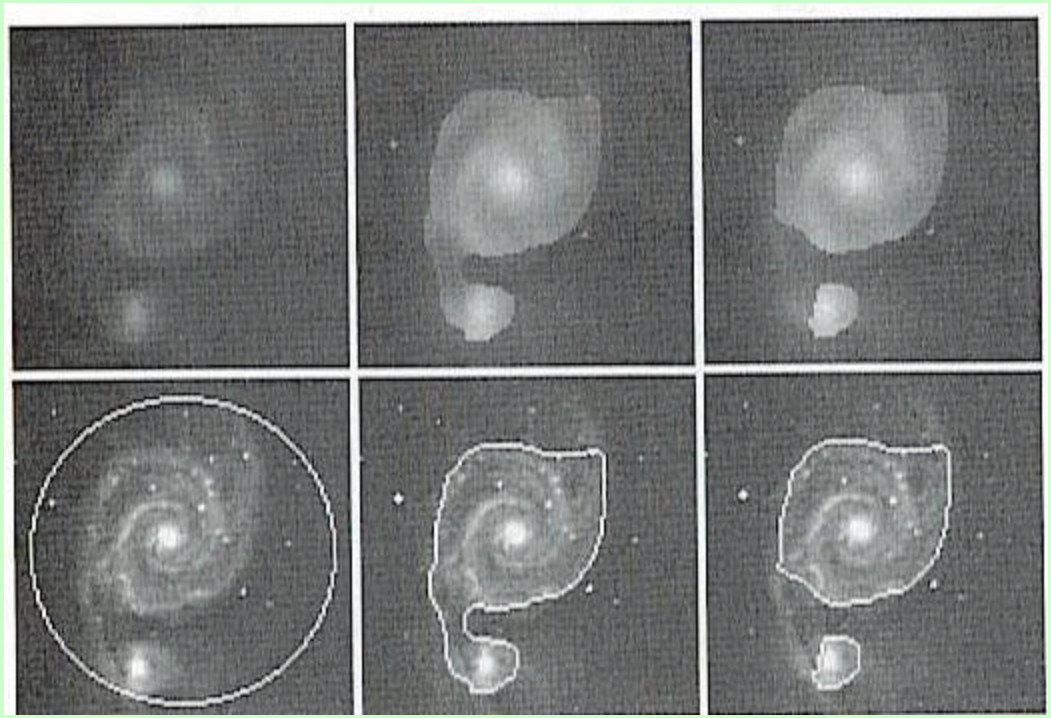


In April, a team of European and American astronomers used Yepun to detect a faint and very red point of light near the brown-dwarf star 2M1207. The astronomers believe they may have taken the first direct image of a planed circling another star.

And Anne-Marie Lagrange "Our discovery represents a first step towards opening a new field in astrophysics:

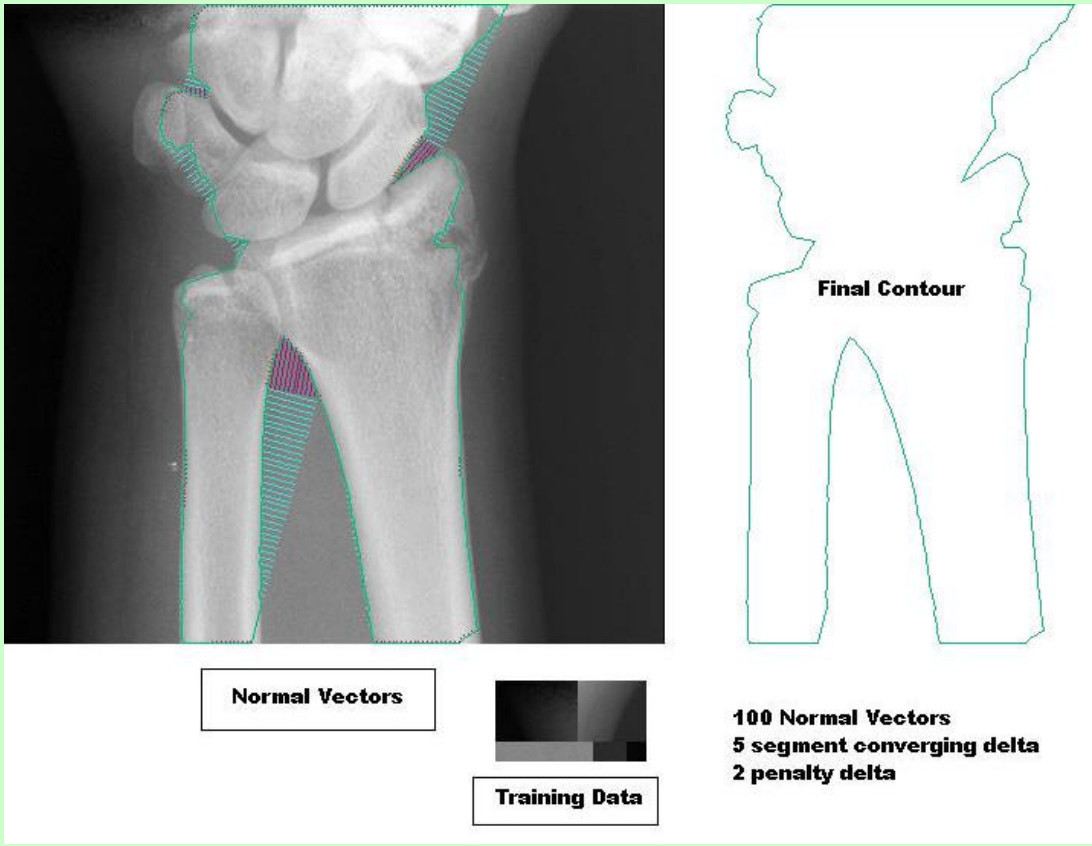
the imaging and spectroscopic study of planetary systems.

SEGMENTATION



Result from the piecewise smooth Mumford-Shah level set algorithm with one level set function

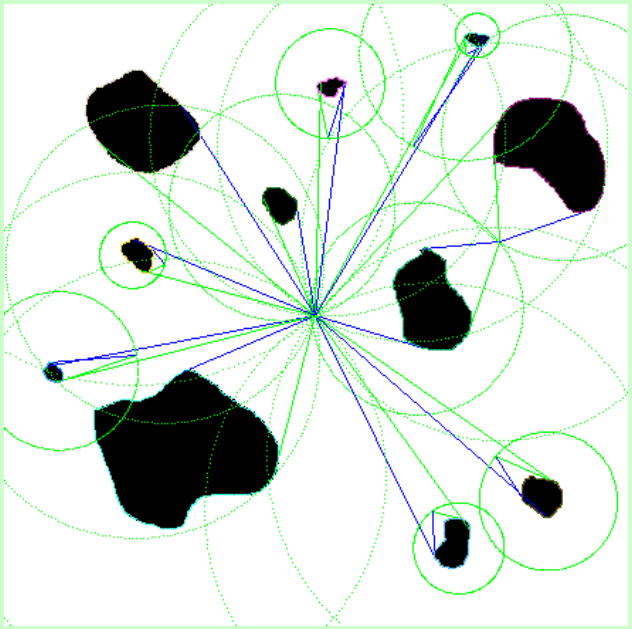
SEGMENTATION



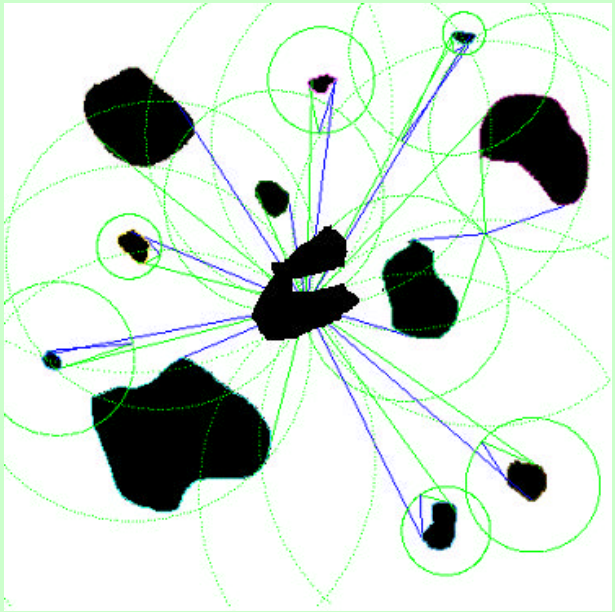
Edge detection and medical X-Ray image segmentation, using curve, evolved according to the Heat DE

Open Problem

a)



b)



We are able to segment a), but not b).

The 2D Convex Hull Algorithem

$$r^{j+1} = r^{j} + d^{j} \partial \vec{t}^{\,j} P^{j} - \vec{T}^{\,j} s^{j} \qquad (8)$$

where

$$r^{j} = \langle r_0^{j}, r_1^{j}, ..., r_n^{j} \rangle \qquad r_i^{j} = r^{j}(t, s_i^{j}) \quad \text{, for } i=1,\ldots,n \qquad r_0^{j} = r_n^{j}$$

$$\vec{T}^{\,j} = \langle \vec{T}_1^{\,j}, ..., \vec{T}_n^{\,j} \rangle \qquad \partial \vec{t}^{\,j} = \langle \partial \vec{t}_1^{\,j}, ..., \partial \vec{t}_n^{\,j} \rangle$$

,

j denotes the time step (parameterization of the family),

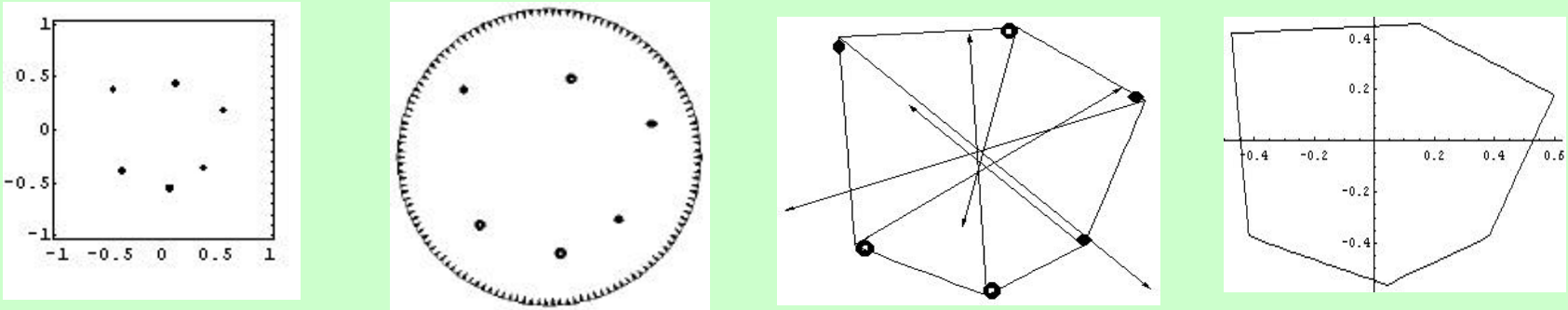
i represents the space step (parameterization of the curve);

s_i^{j} denotes the length of the i-th curve's arc segment at time j.

P^{j} denotes the values of the penalty function in the form of an nxn matrix:

EXPERIMENTAL RESULTS

Figure 7. a) A vertebra in an image of size 64x64.
b) The evolved curve after 500 iterations.
c) The convex hull after 1000 iterations.



Open Problems

2) To code the algorithm in C++;

3) To develop the theoretical base of the 3D case and code it by Mathematica or MathLab or C++.

Heat Differential Equation to Image Segmentation-THE 3D CASE

The 3D model based on the 3D geometric heat DE

$$\frac{\partial S}{\partial t} = PH \frac{\vec{N}}{\left\| \vec{N} \right\|}$$

where $S = Family\ of\ surfaces$

$H = Mean\ curvature$

$\vec{N} = Inward\ normal\ vectors$

$P = Penalty\ Function$

Parameterization

The surface *S* is represented by the following vector function:

$$r(t,q,f) = \langle x(t,q,f), y(t,q,f), z(t,q,f) \rangle$$

where

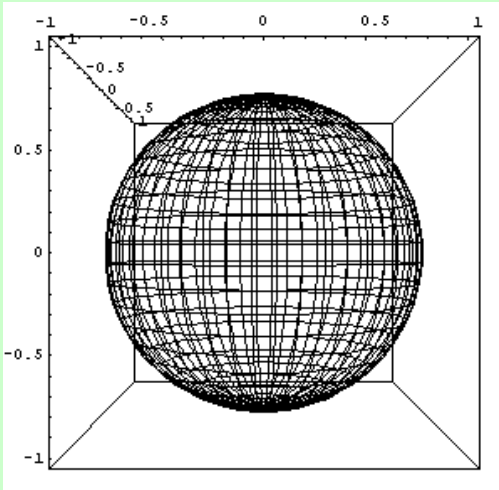
$t = Time\ parameter\ which\ parameterizes\ family\ of\ surfaces\ with\ t \in [0,\infty)$

$q = Space\ parameter\ where\ q \in [0,2p]$

$f = Space\ parameter\ where\ f \in [0,2p]$

The initial surface is defined for *t=0*:

$$r(0,q,f) = \langle \cos q \sin f, \sin q \sin f, \cos f \rangle$$



THE 3D ALGORITHM

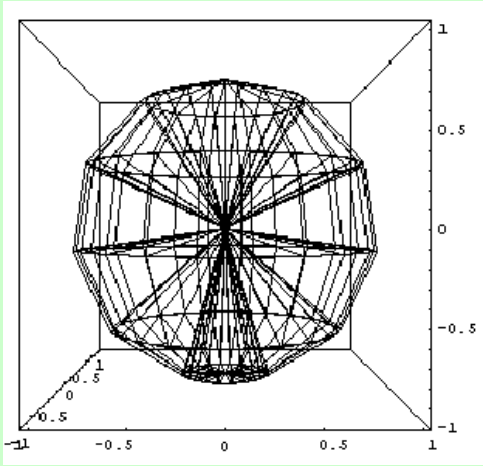
Using central differences we rewrite our theoretical model as an iterative process:

$$r_{ik}^{j+1} \approx r_{ik}^{j} + d_{ik}^{j} P_{ik}^{j} H_{ik}^{j} \frac{\vec{N}_{ik}^{j}}{\left\| \vec{N}_{ik}^{j} \right\|}$$

where

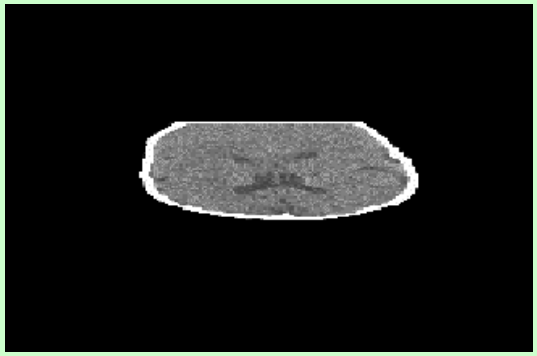
$$\left.\begin{array}{l} j = 1, 2, \ldots \end{array}\right\} \text{Time}$$

$$\left.\begin{array}{l} i = 1, 2, \ldots, n \\ k = 1, 2, \ldots, n \end{array}\right\} \text{Space}$$

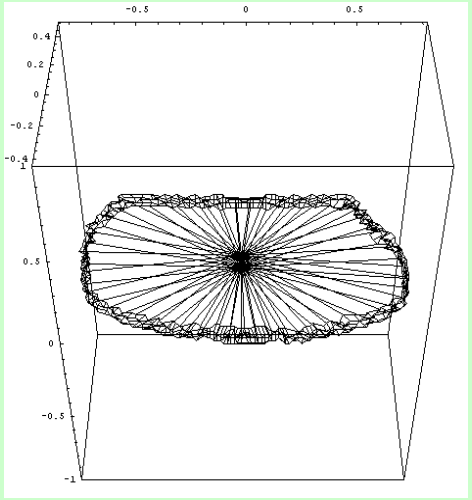


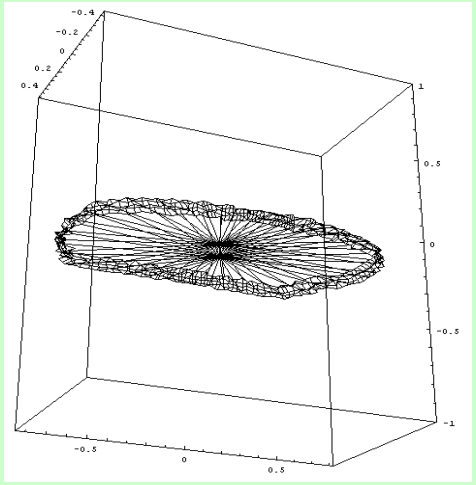
The vector field if n=12

Results



Brain's 2D section.





Brain edges from 5 2D sections.

Open Problems

4) To code an algorithm for painting the reconstructed surface:

5) To code the algorithm in C++;

6) To make the 3D model working with more than one object and code it by Mathematica or MathLab or C++.

Image Database and Features

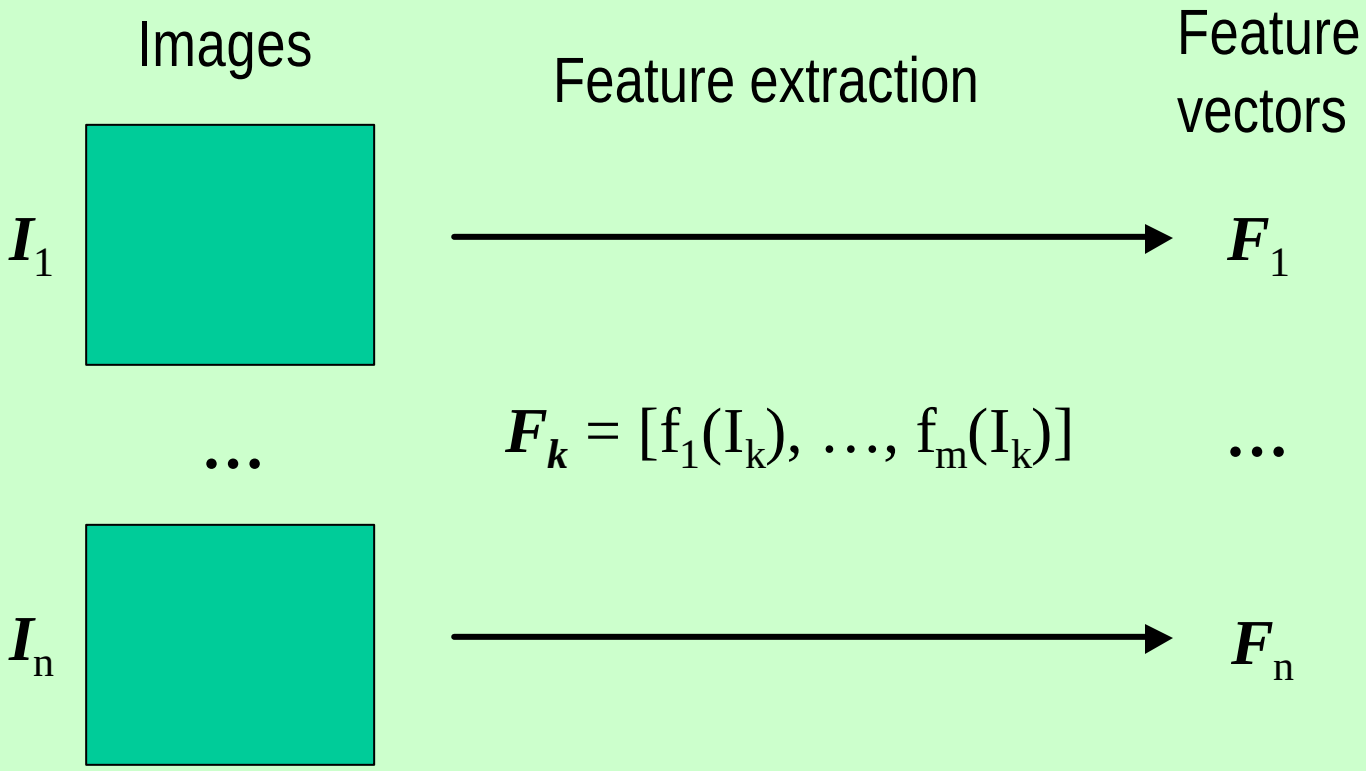
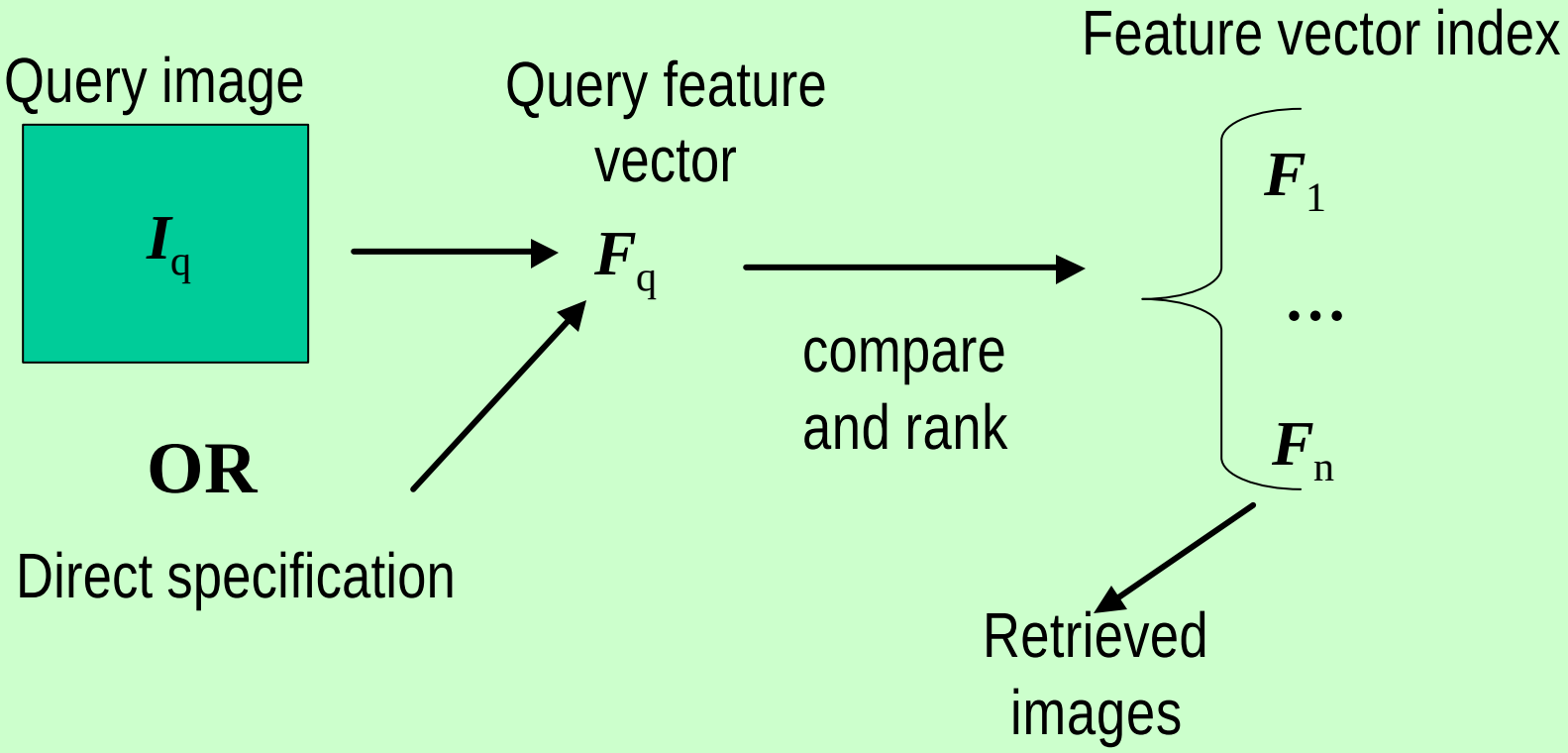


Image Database Query

Two common approaches:

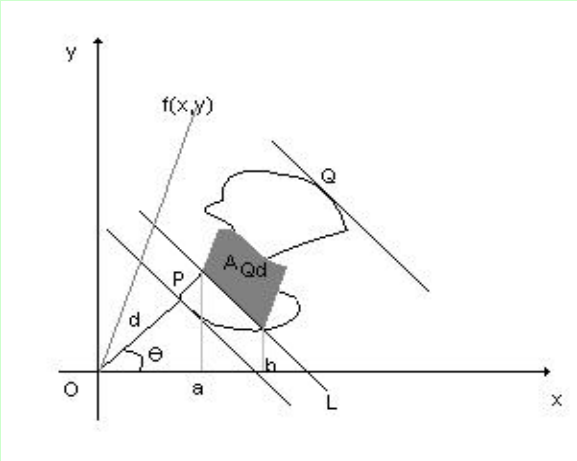


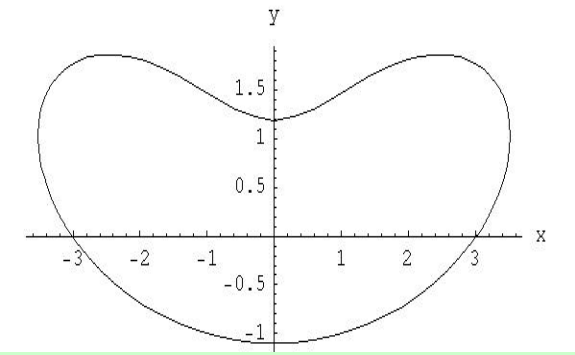
Open Problem

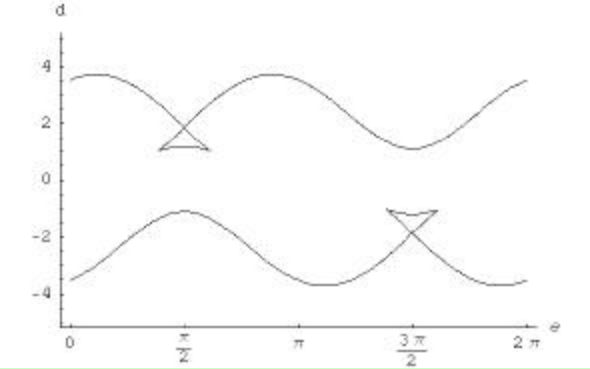
7) An algorithm and tool for image database mining for shape features extraction and indexing:

Concavities-Boundary Support

Definition



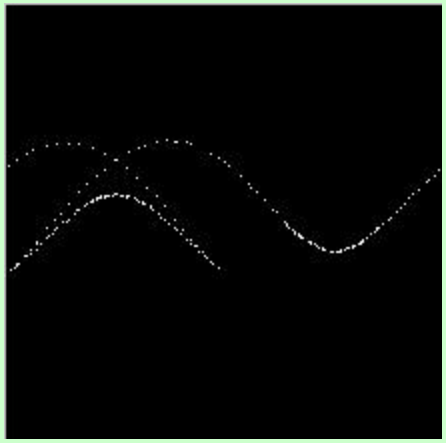




a) An object **b) its boundary support**

Concavities-Boundary Support

a) 

b) 

a) A section of an impermeable subsurface unit.

b) Its boundary support obtained by C++ tool.

Open Problems

8) To determine the correlation between the area of

a boundary concavity and the area of the loop, that corresponds to the concavity, on the support.

9) C++ tool for matching objects by using boundary support.

DEMONSTRATIONS

1. **BLOBWORLD**
2. **RetReg ; Results .**