Fourier Descriptors For Shape Recognition

Applied to Tree Leaf Identification

By Tyler Karrels

Why investigate shape description?

- Hard drives keep getting bigger.
- Digital cameras allow us to capture, store, and share picture like never before.
- Personal computers and electronics are now focused on multimedia.
- A good method of shape description will have many applications.

What does this add up to?

- Huge media databases have accumulated all over the internet and in industrial applications.
- Searches should return relevant data.
- In the case of images, we need metadata describing an image’s contents.
- A powerful method to recognize objects uses the Fourier Transform.

Why did I choose this project?

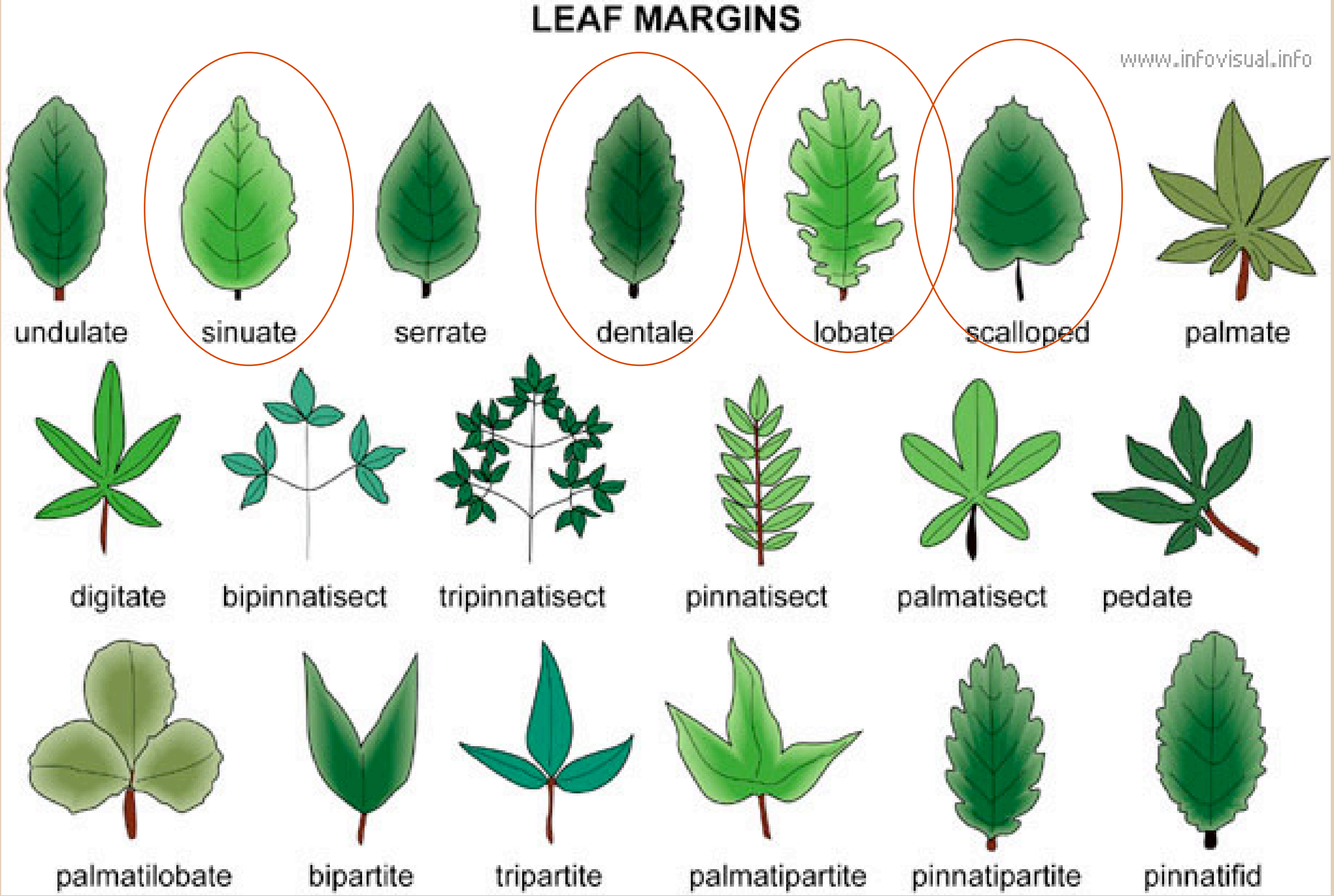
- Fourier descriptors have been used in many applications before.
- Built on previous vowel recognition project.
- I have an interest in nature.
- Leaves seem like a great example of shapes.
- Subtle differences in shape test the limits of Fourier Descriptor methods.

Research Conducted

- Read several papers on various Fourier descriptor applications.
- Leaf classification has been done before.
- Learned of various shape signatures.
- Found a better distance measure, Time Warp Distance.

Different Leaf Shapes

FDs is not a good technique for identifying compound leaves.



Preparation

- Needed a database of leaves.
- Collected leaves from 6 species.
- Took over 200 pictures of various orientations.

Leaf Samples






Theory

Imagine a picture with a square in it.
A useful shape representation should be…

- Scale Invariant

  - A big square and a small square should both be classified as squares.

- Shift Invariant

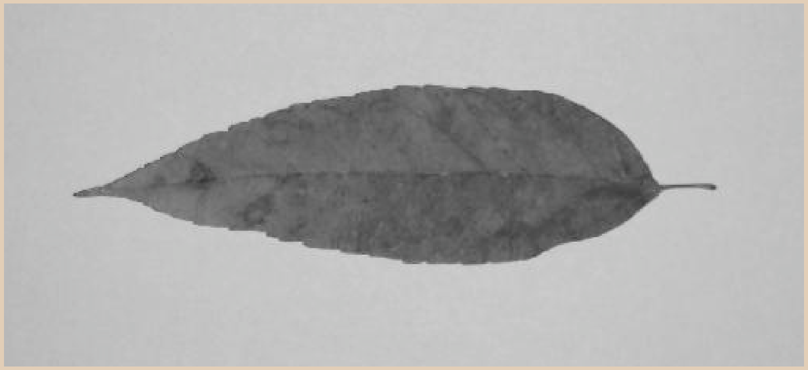
  - Where the square exists in an image should not affect performance.

- Rotation Invariant

  - Any rotated version of the square should be recognized.

The Centroid Contour Distance Curve (CCDC) ***can*** satisfy these with proper modifications.

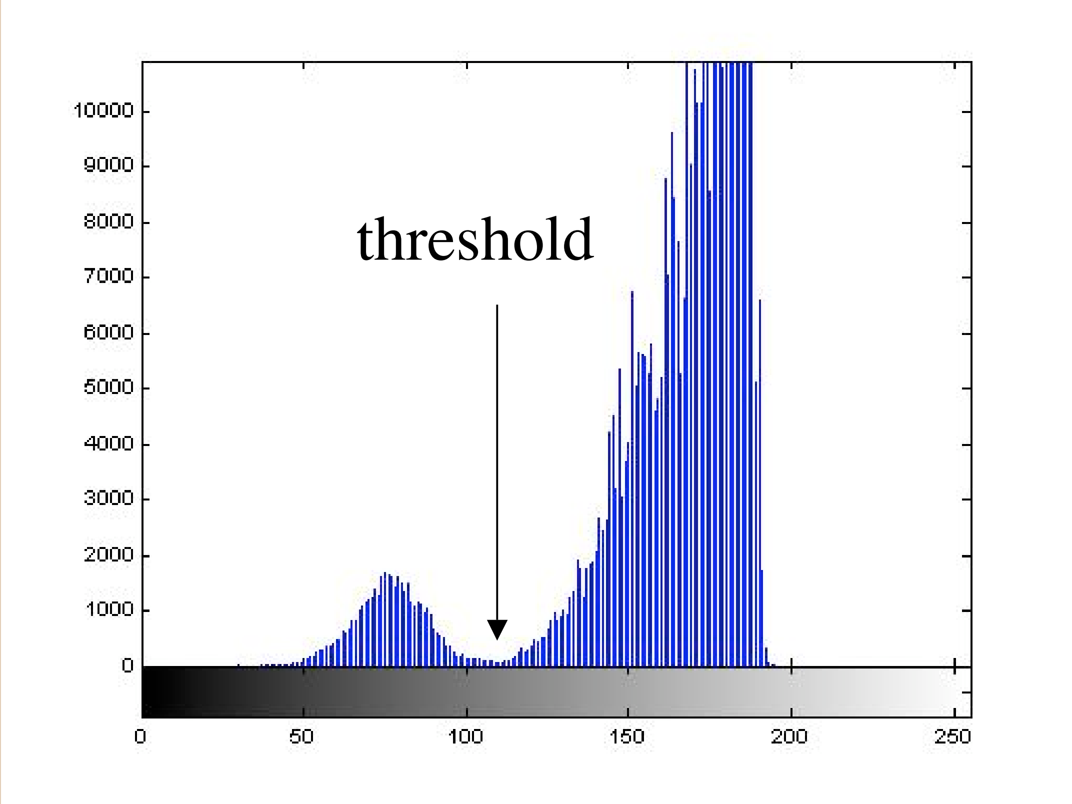
Method to Compute FDs

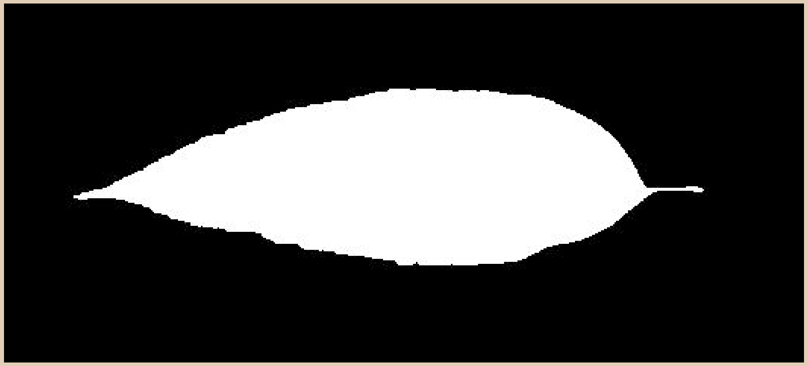


1. Reduce the resolution by a factor of 6
   - original is 3 Mega pixels, now 0.5 Mega pixels
   - increases speed of future calculations

2. Convert original image to grayscale image.

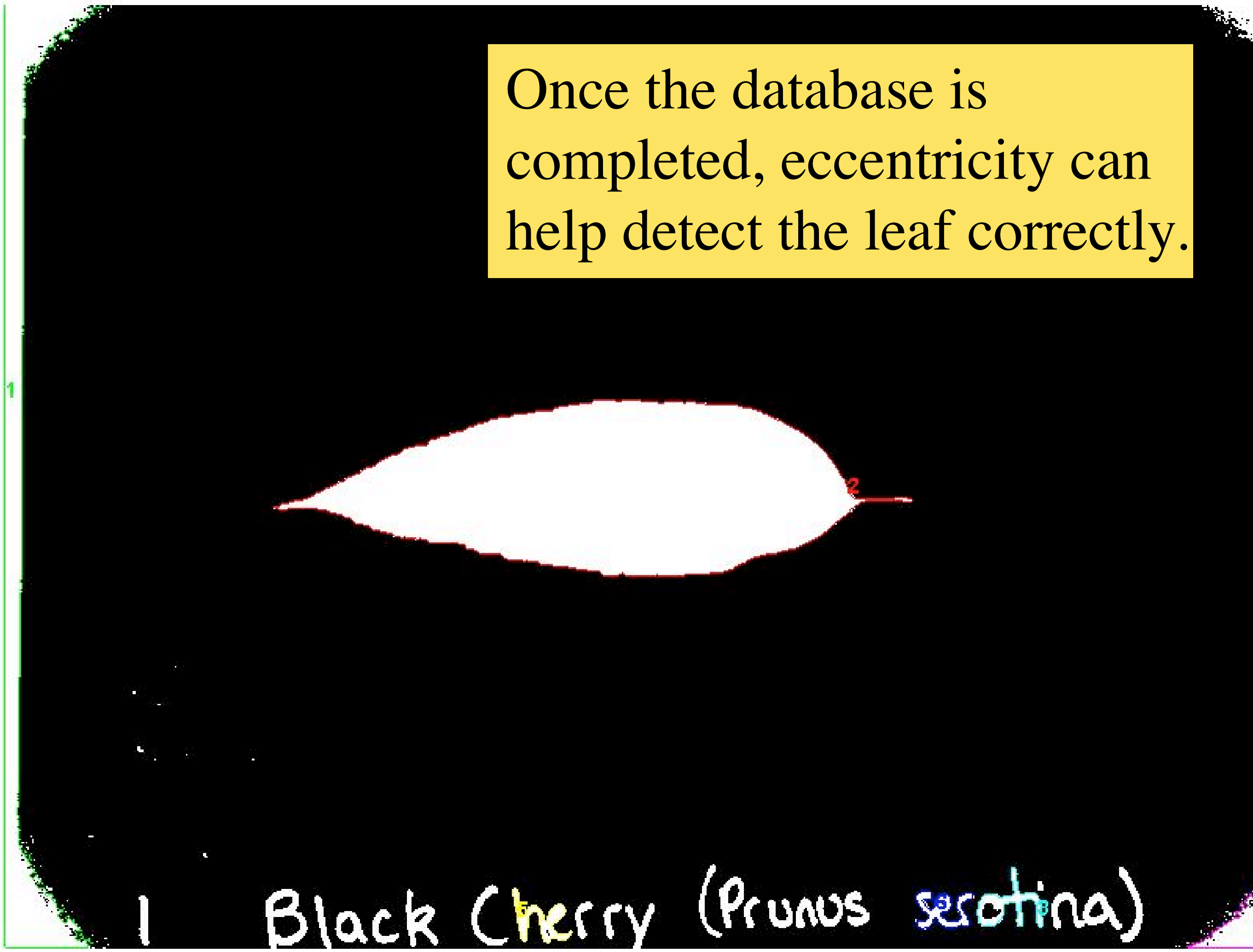
(Black Cherry Tree Leaf)





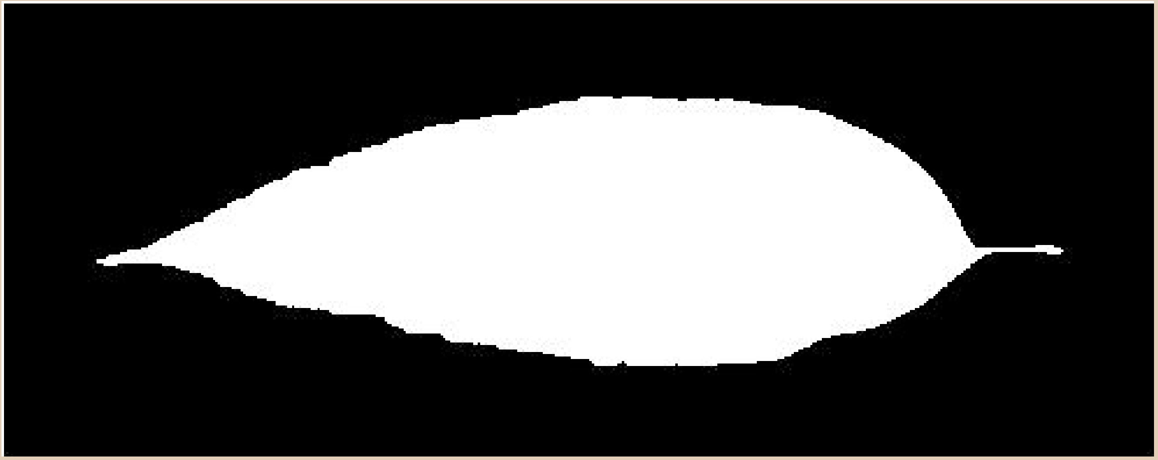
3. Calculate an appropriate grayscale threshold.
4. Threshold to produce a binary image.

5. Find and label 6 longest boundaries in the image.
At this point, the user must select the leaf's boundary.

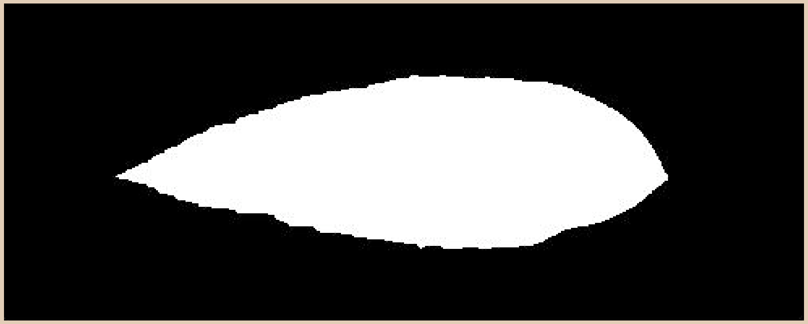


Once the database is completed, eccentricity can help detect the leaf correctly.

After the leaf is identified it is extracted from the larger image with some additional zero padding.

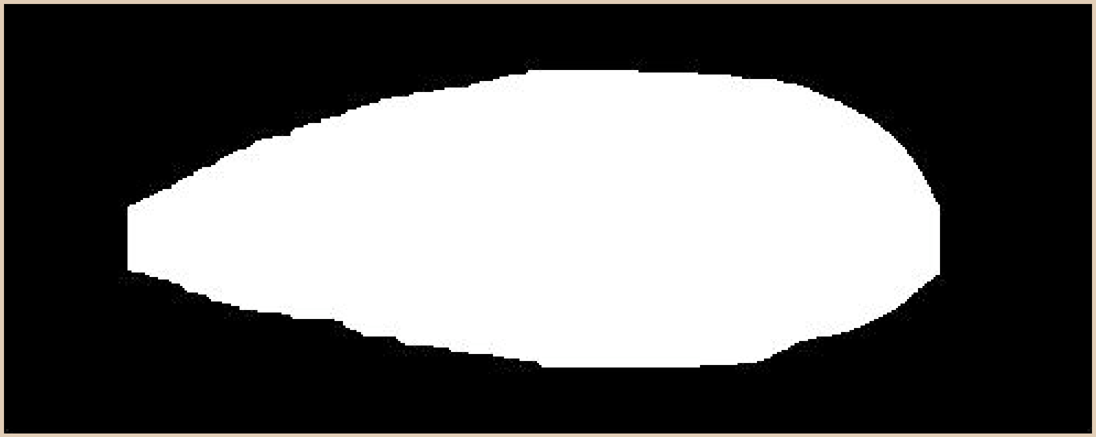


6. Fill in any interior holes in the leaf.



7. Remove stem by erosion with a square of size 10x10 pixels.

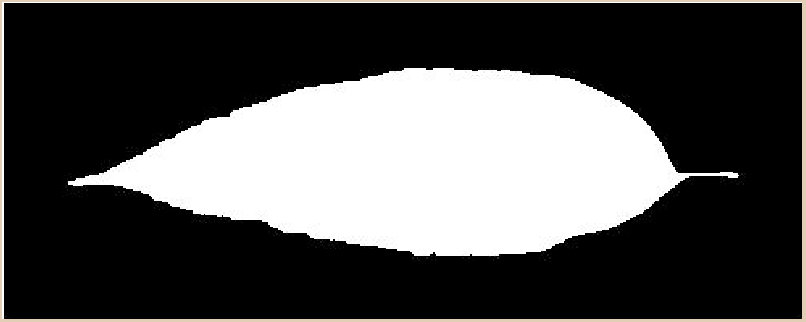
Next create a window to overlay on leaf image to extract the stem.



8. Dilate a few times by 15 pixel square to enlarge the image of the leaf with no stem

• The goal is to create an area larger than the leafs area so we can subtract the images.

• Notice that we cannot reconstruct the sharp points of the leaf.



Original Leaf

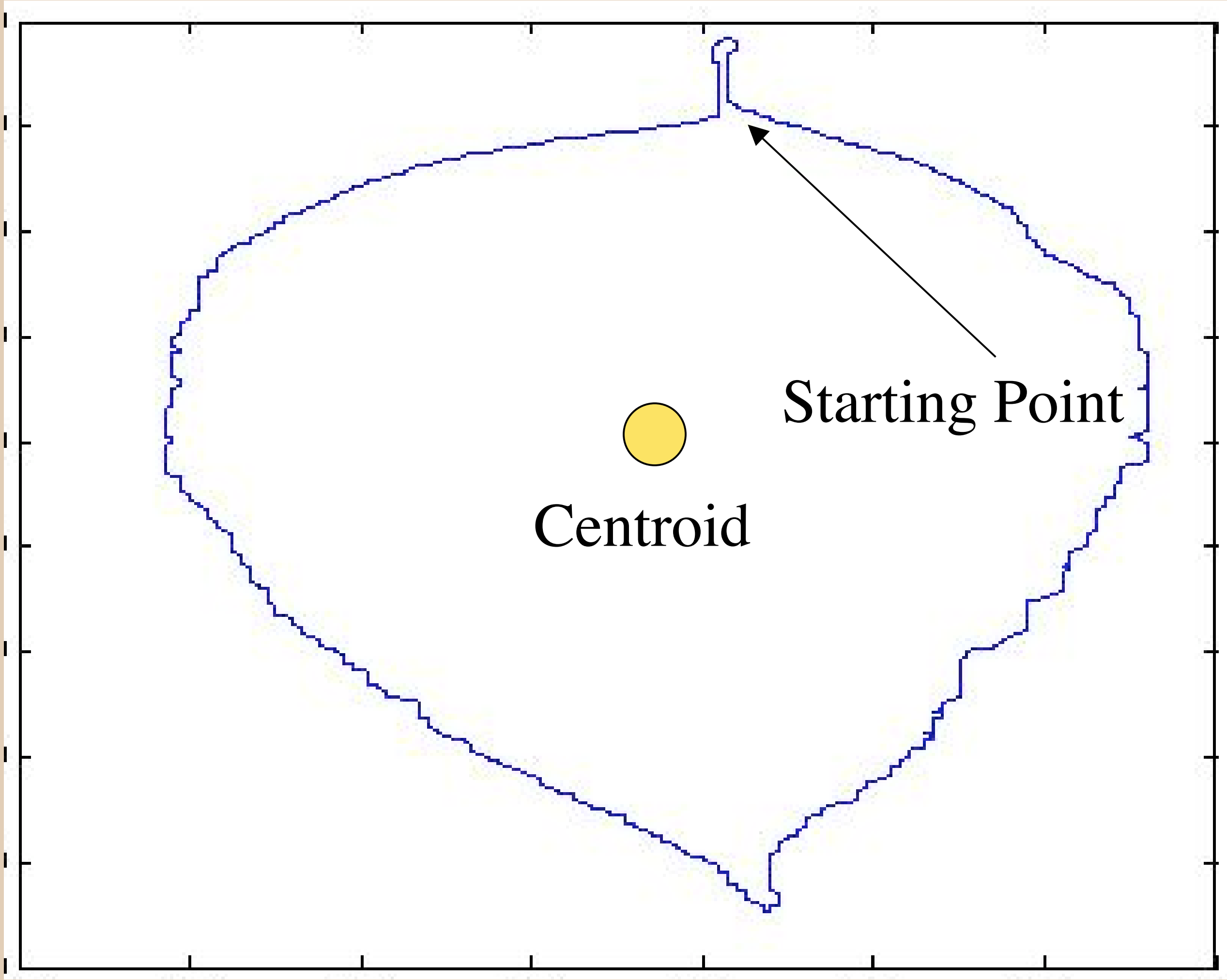
The window is subtract from the leaf and the resulting image is again thresholded to convert back to binary image (removes -1 entries).

9. Select the area with longest boundary. This should be the leafs stem.

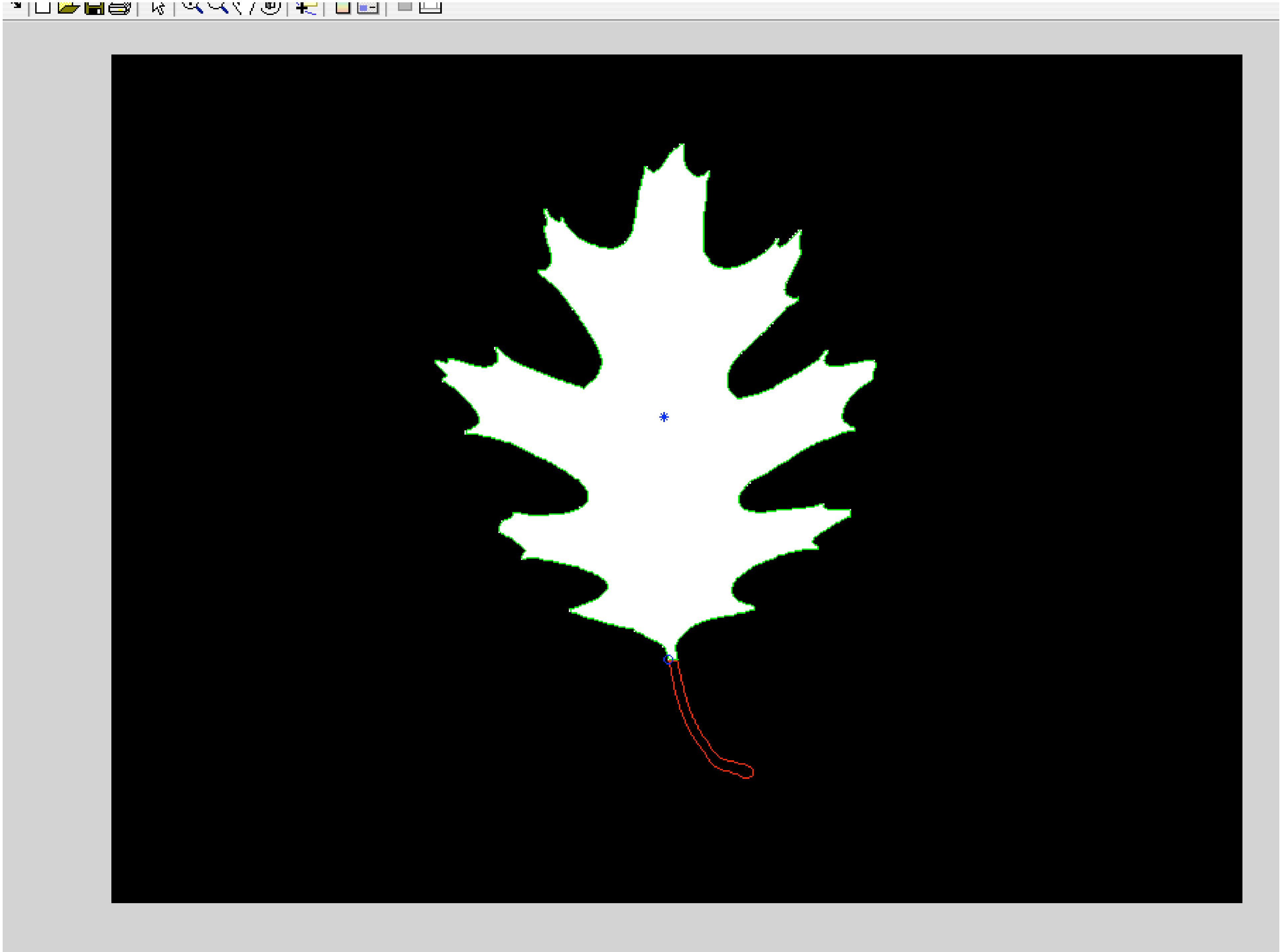
- The point on the stem closest to the leaf body will be the starting point of the boundary sequence.

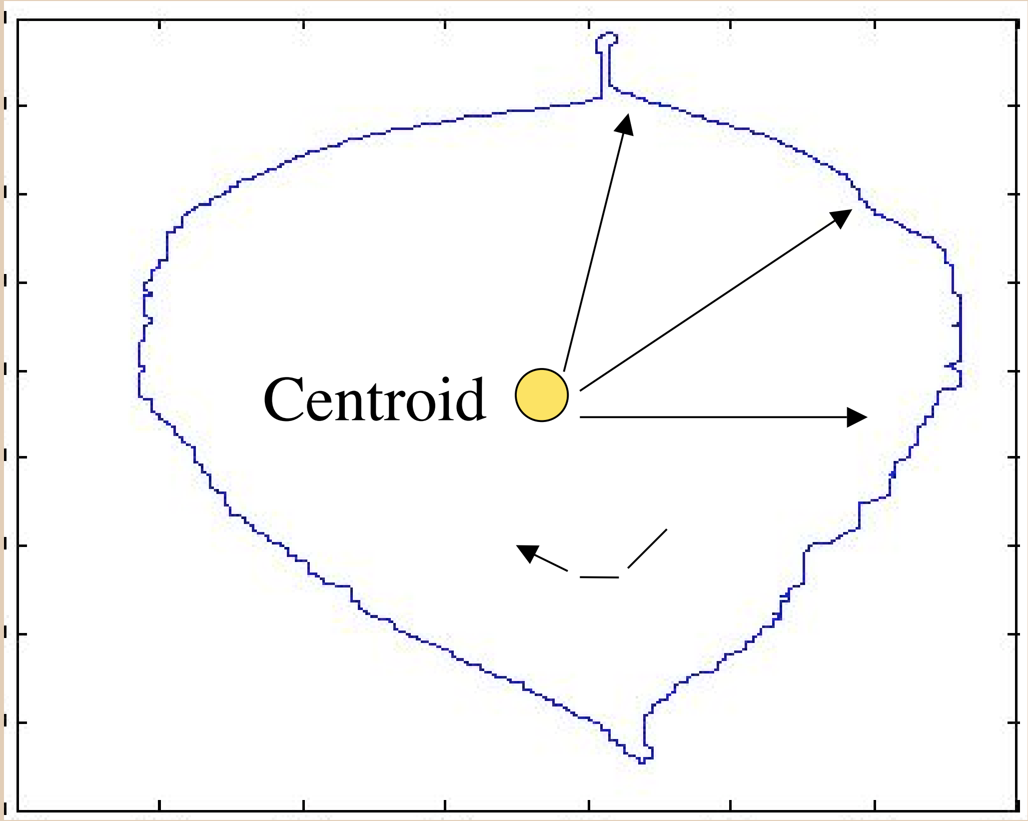
Extracted Stem (enlarged)

- Assuming a stem is present this method should accurately reproduce the same starting point on different leaves giving us a rotation invariant representation.

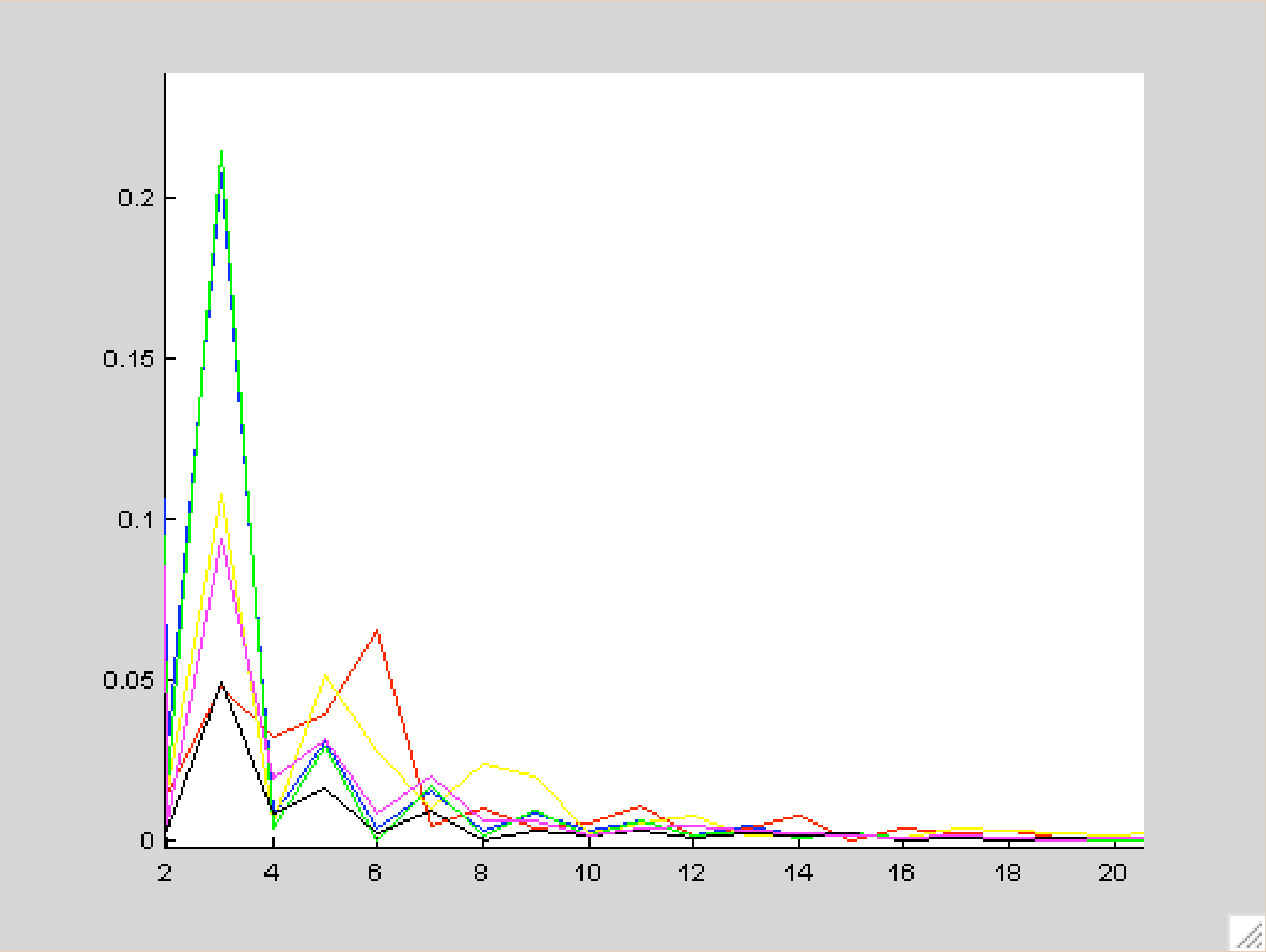


10. Calculate centroid.





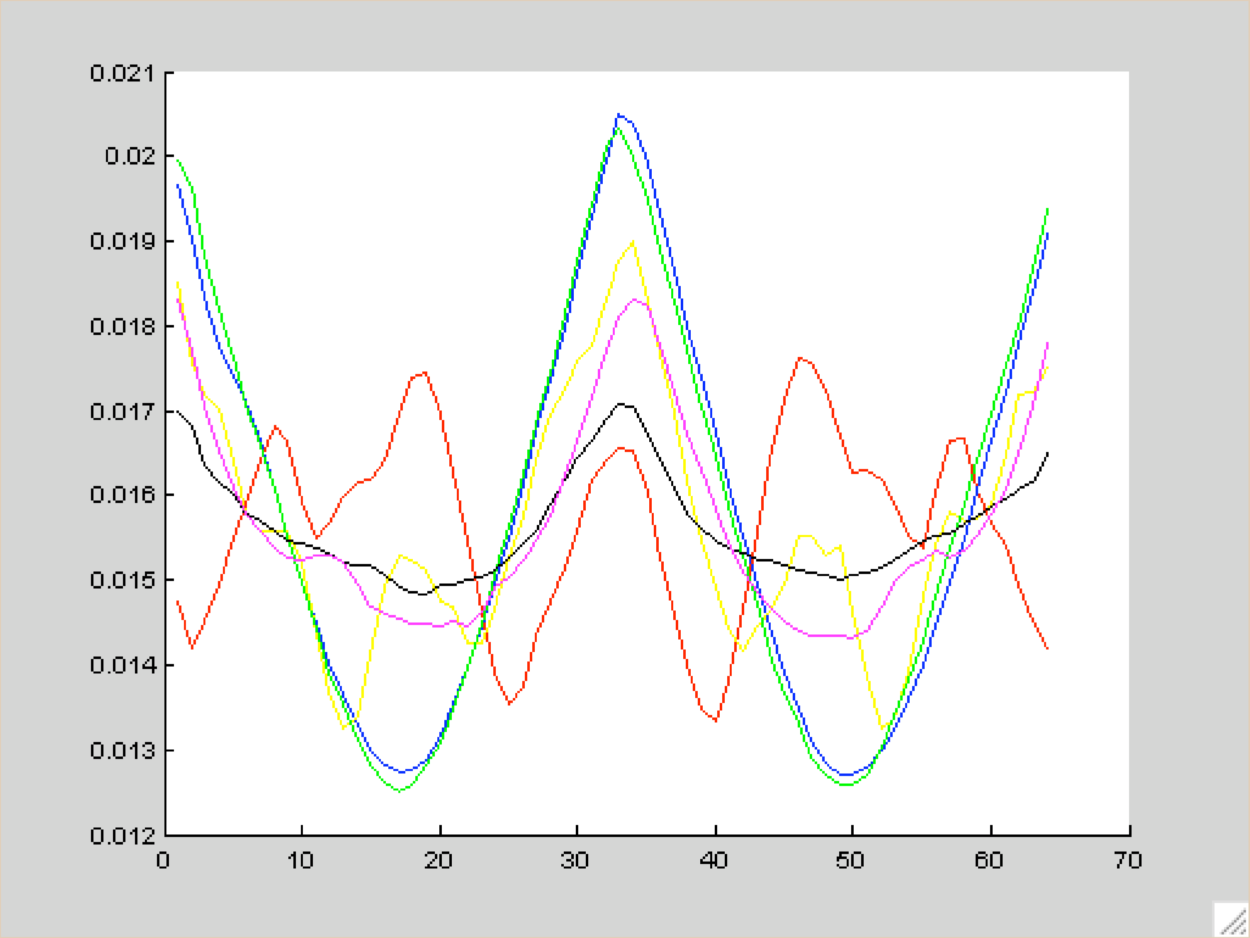
11. Calculate the Centroid Contour Distance Curve (CCDC) in the clockwise direction, beginning at the derived starting point.
12. Approximate the boundary with the first 64 coefficients, and scale to [1,0] range for scale invariance.



The prototype Fourier descriptors for each class.

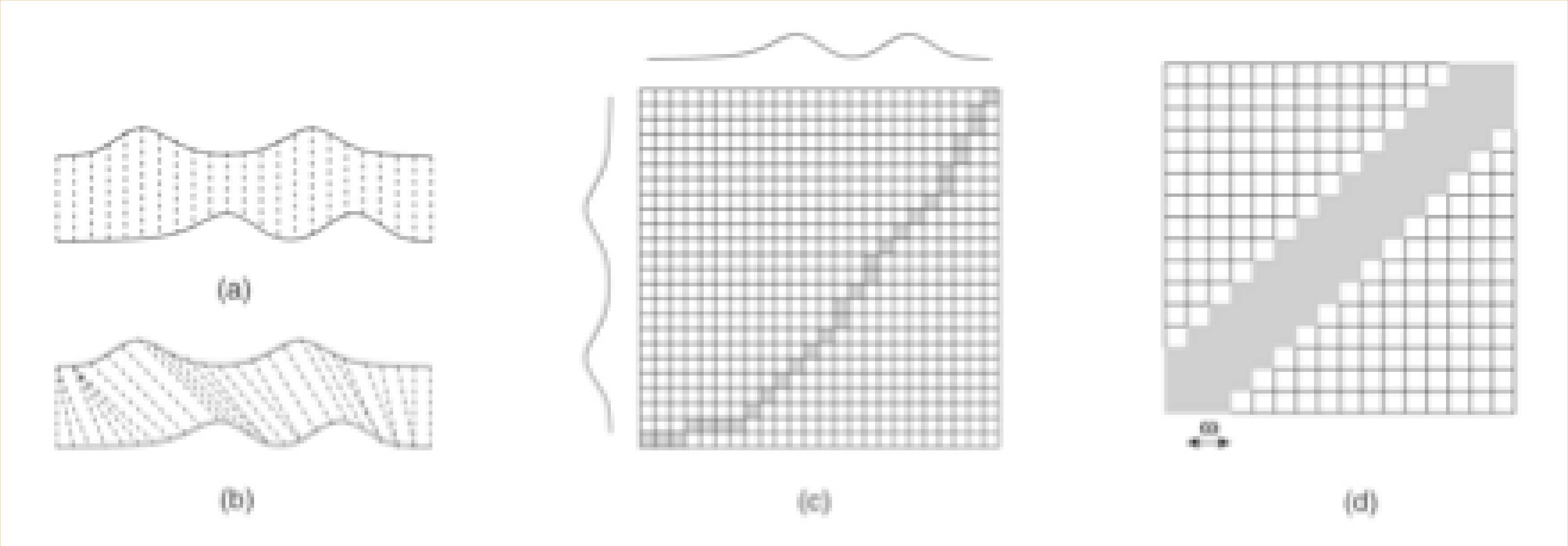
Classification Method

- Calculate FDs with previous method.
- A prototype FD for each class if calculated as an average of all database entries.
- FDs are converted to the time domain with IFFT for comparison.
- Using Time Warp Distance, the closest class is chosen as the leaf type.



The prototype centroid distance curves for each class.

Time Warp Distance



- Lines up prominent peaks and valleys between two sequences.
- Parameter allows control over how much phase shifting takes place.

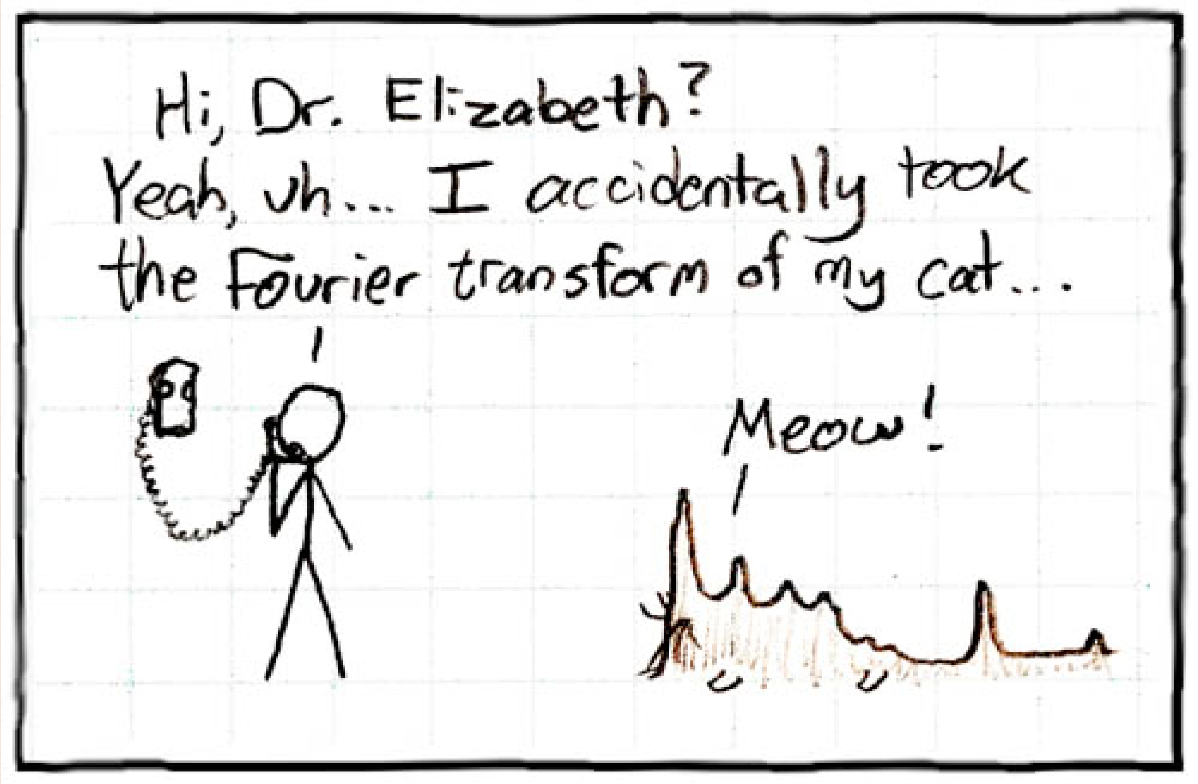
Test Results

Correct	Test Size	Restrictions	% Correct	Guess %	x Better	Test Vector
17	32	none	0.5312	0.1667	3.1872	random
18	32	none	0.5625	0.1667	3.3743	random
18	32	none	0.5625	0.1667	3.1872	random
16	32	none	0.5000	0.1667	2.999	random
21	32	no shrub	0.6562	0.2	3.281	random
21	32	no shrub	0.6562	0.2	3.281	random
23	32	no shrub	0.7188	0.2	3.594	random
20	32	no shrub	0.6250	0.2	3.125	random
27	32	no shrub	0.8438	0.2	4.219	random

Discussion

- Threshold technique worked only 80% of the time.
- Manual leaf selection can be removed, may introduce further errors.
- Skeleton method to derive starting point was inefficient.
- CDC was used because it was translation invariant to begin with, captures periodic nature of leaf.
- Angle code histogram would have improved results, especially between cherry tree and shrub.

Thank You For Your Attention!



Questions?