CS 7960, Advanced Image Processing
Spring 2010, Prof. Guido Gerig

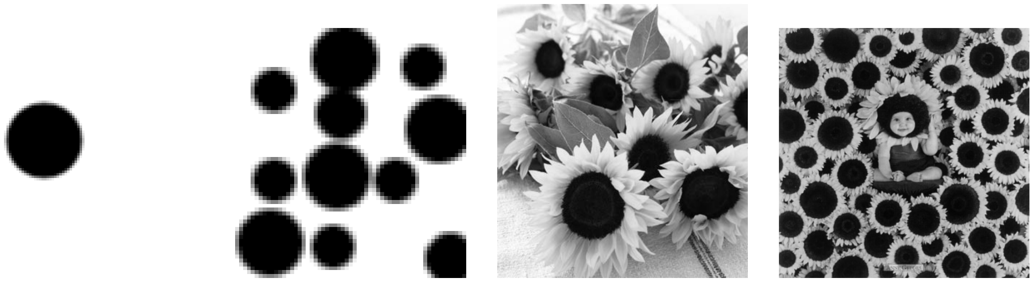
Project 1: Scale-Space Selection

Out:	Tuesday Jan-27-2010
Due:	Tuesday Feb-11-2010 (theoretical and practical parts)
Office hours:	Tue 1pm to 3pm, please contact me in advance or for other arrangements.

Required Readings: FEV chapters 1 to 5, slides

1 Blob segmentation by scale selection

The goal of this project is the implementation of a method that tries to find the centers and the size of blobby objects via scale-space analysis. Typical images are shown in Fig. 1. Following discussion in class and as described in the FEV chapters, expanding the images into a scale space might show similar *signatures* for discs of different sizes, just presented at different scales.



onecircle.png scalespaceTest.png sunflower2.png sunflower3.png

Figure 1: Image data showing one disk, a selection of disks of different size, and two images of sunflowers.

The key element of your program is the fact that the best matched filter to a disk is the Laplacian of a Gaussian (Laplacian at the appropriate scale). Just think about a convolution of the image with a "Mexian Hat" operator, which is often used as the model shape for a Laplacian. Given an image with a set of disks, you generate a Gaussian scale-space and then apply the Laplacian to obtain the second derivative at each scale. The optimal scale for each disk is characterized by a maximum filter response at the center of the disk, with smaller and larger scales presenting lower responses. This shows that you need to apply a maximum operation in space and also across scales to find the centers of the blobs. The location of the maximum characterizes the position, and the scale the size of each disk. By selecting optimal scales you therefore get a segmentation of the blobs with center and width.
Please note that the implementation strategy outlined below is just one possibility, there are many ways to implement a Gaussian scale space or Laplacian scale space, respectively (e.g. via Fourier transform, heat equation and more). A good candidate method is the iterative implementation via the head equation, where the image is iteratively updated with the Laplacian-filtered image in discrete time steps. This would not create a logarithmic range of scales, but with the relationship $t = \sigma^2$ one can select the log-scale set of images for further processing.

A possible strategy for your program is outlined below:

- Read one of the images (see Fig. 1), best is to start with the single blob for testing your method.
- Expand the image into a Gaussian scale space. Choose a scale range of σ in units of e^t, with t ranging from $1 \cdots 3$ with 0.1 units, for example.
- Filter each scale by a discreate Laplacian kernel. Since the intensity decreases with increasing scale, you need to multiply the image intensities by σ^2 for normalization, resulting in a normalized detector for blobs.
- Detect maxima in space and scale, i.e. a candidate pixel is a maximum in rows and columns but also across scale. Create a list of these maximums, with an index for (x,y)-position, scale σ and also filter response which characterizes the blob strength. This list represents the full segmentation result.
- Display the results as circles with width $1.5*\sigma$ at the resulting positions (x,y), and eventually overlay these with the original images to verify your results. The factor 1.5 indicates proportionality between scale and the object size, and can be derived through analysis of the response from the blob detector (Lindeberg 1994).
- Analyze the results to demonstrate scale-invariant representation of objects, i.e. smaller blobs appear at lower scales than larger blobs, but showing similar signatures (blob strength).
- Apply procedure to the two synthetic blob images but also to the two sunflower images. You might search for other pictures of your choice.

You should write up a report summarizing your procedure and discussing your results. The report should be **written in html** and **accessible to the instructor via a web-browser**.

- Description of method to create scale space.
- Description of Laplacian filtering.
- Short description of maximum detection strategy.
- Applications to all images and illustration of results as pictures, graphs and the list of detected blobs.
- Discussion of:
  - Correctness of resulting blobs.
  - Robustness of algorithm w.r.t. noise and neighboring objects (close objects merge at larger scale and might result in new maxima not presenting disks.
- Commentary about any issues that arose, ways for alternative implementations, potential improvements etc.