Motion Analysis

Optical flow computation:

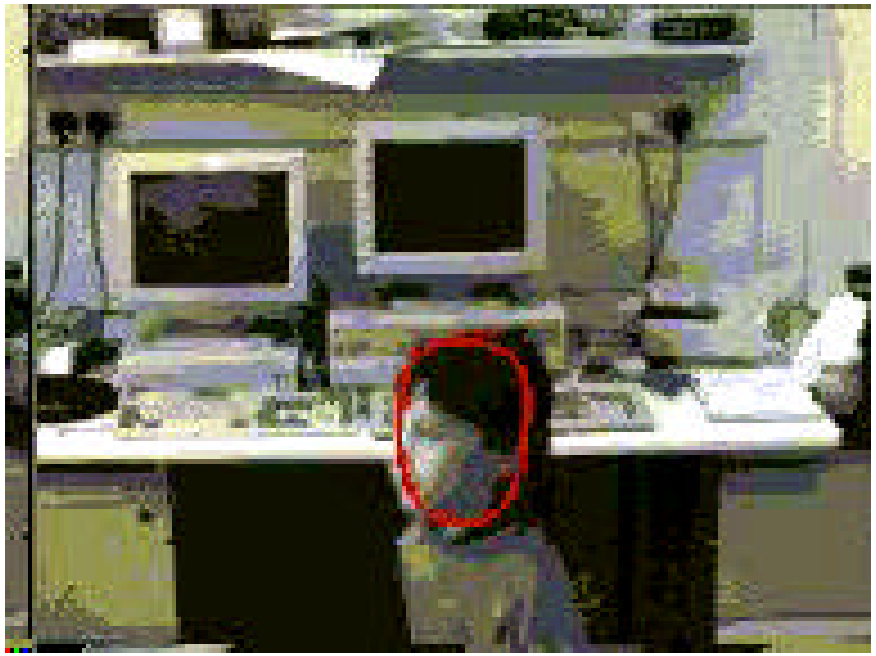
- **Motivation**
- **Theory**
- **Application**

First a few examples...

courtesy of M. Isard

Example applications:

Security: tracking intruders.



Actor-driven facial animation.

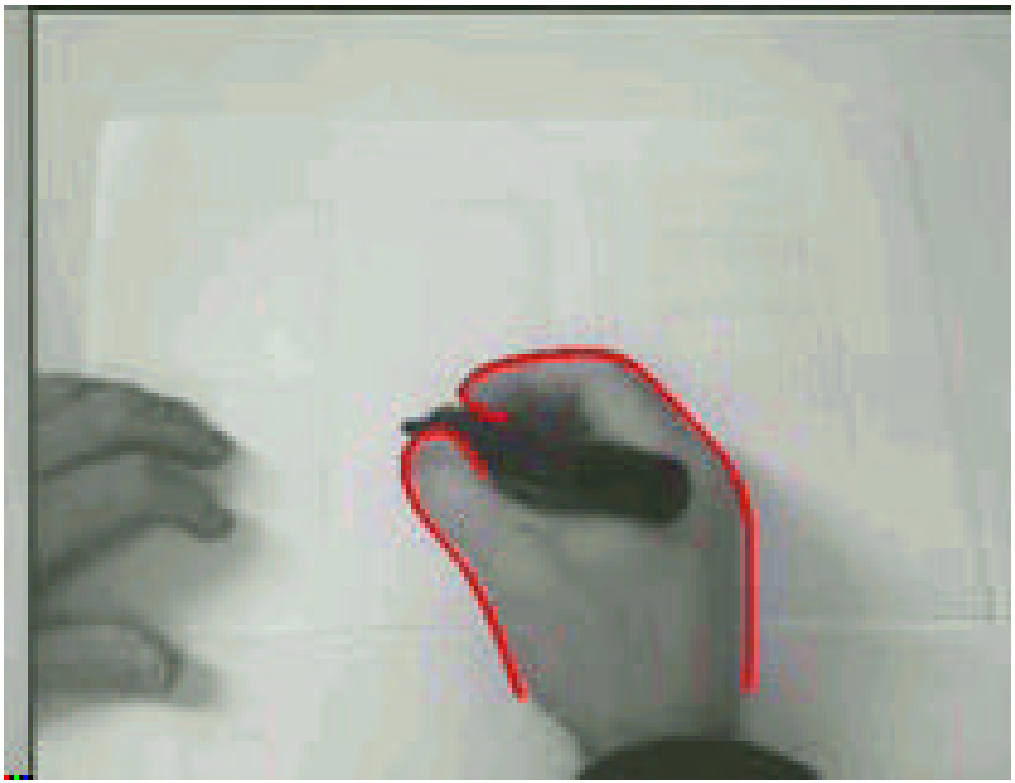
courtesy of B. Bascle

Automated
video editing.

courtesy of M. Isard

Computer-user interaction.

courtesy of M. Isard



courtesy of B. Bascle

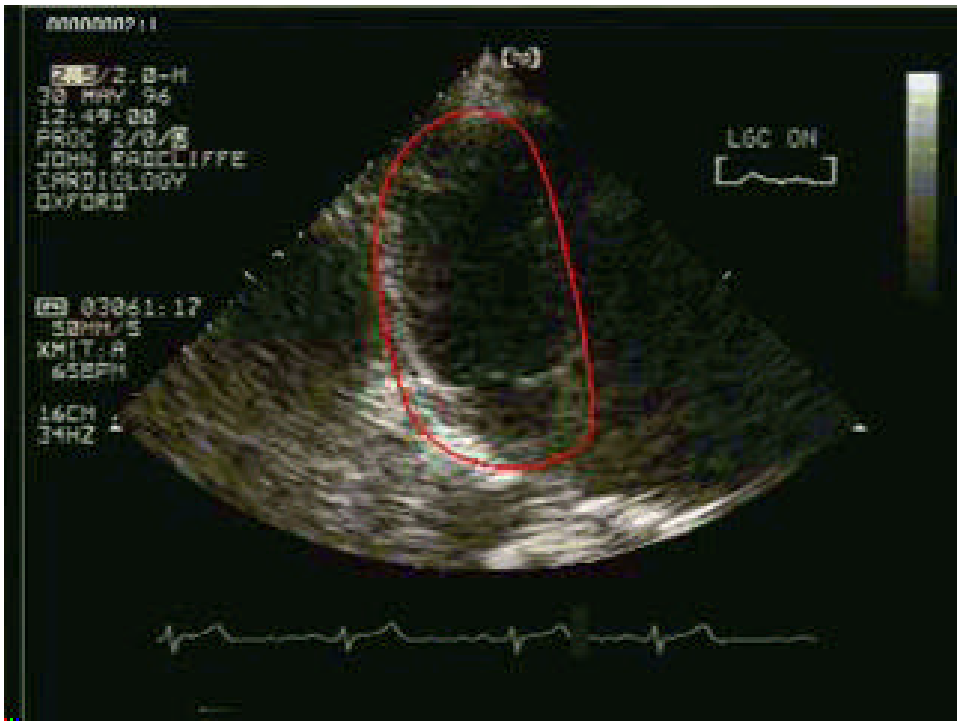
Biometrics: Body Motion.

Note the systematic motion pattern

courtesy of Gary Jacob

Medical applications:
Echocardiogram analysis.

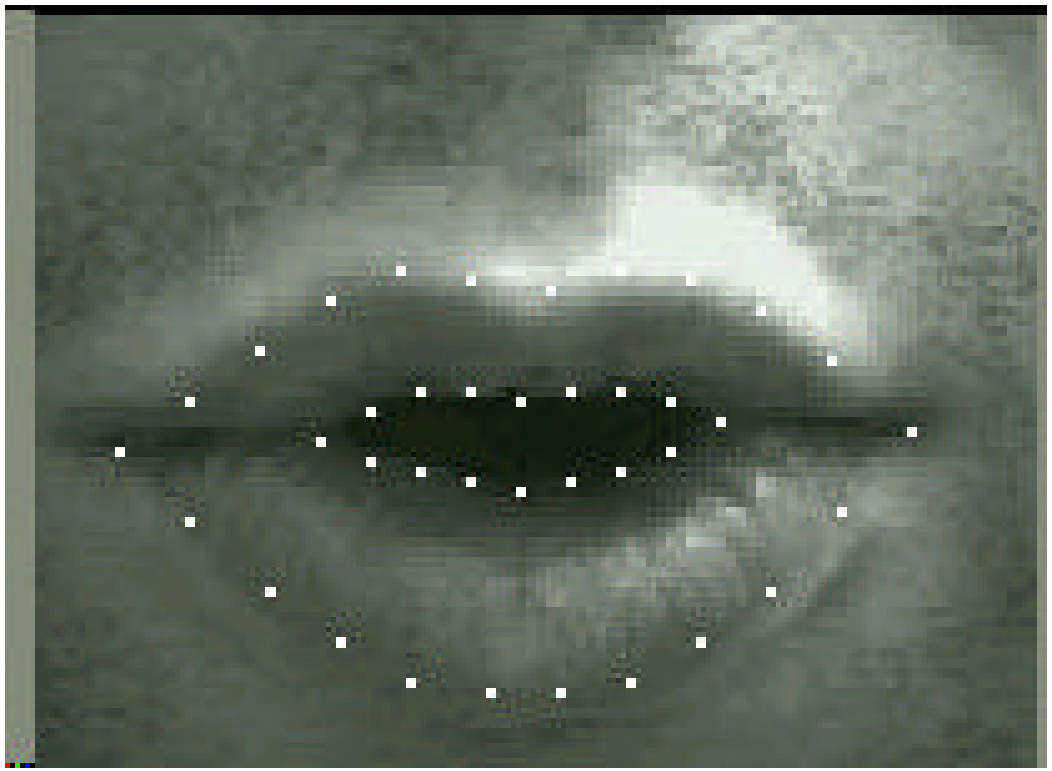
Note the systematic motion pattern



Audio-visual speech analysis.

Note the systematic motion pattern

courtesy of Juergen Luettin



And now some theory...

Optical Flow

Dynamic image $f(x, y, t)$

Constraint 1: Brightness of any object point is constant over time

$$f(x+dx, y+dy, t+dt) = f(x, y, t)$$

Taylor series expansion

(neglecting higher order terms for small *dx*, *dy*, *dt*)

$$f(x, y, t) + f_x dx + f_y dy + f_t dt + o(\partial^2) = f(x, y, t)$$

$$u = \frac{dx}{dt}, v = \frac{dy}{dt}$$

$$f_x u + f_y v + f_t = 0$$

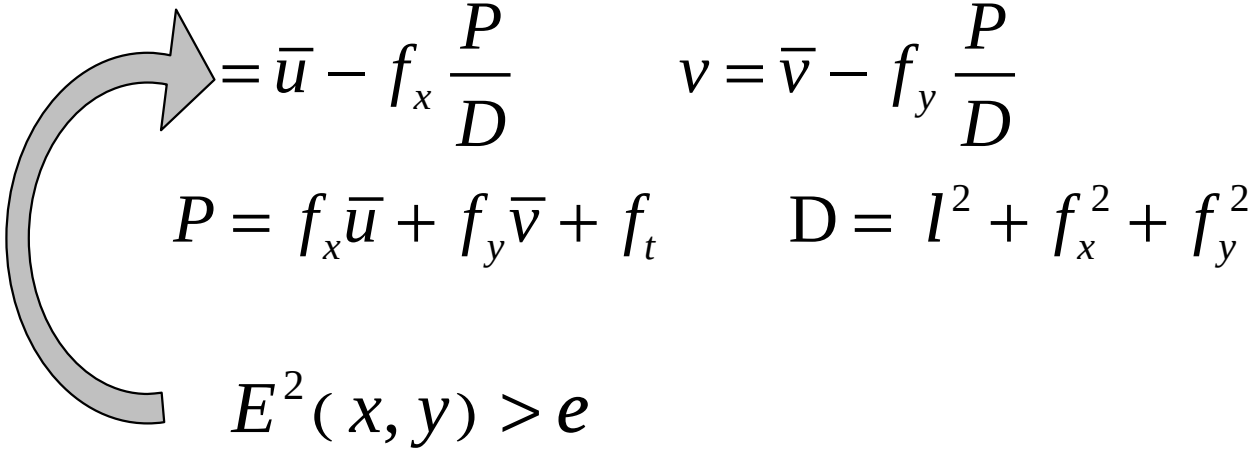
Aperture problem =>Constraint 2: Velocity smoothness

Minimize square error

$$E^2(x,y) = (f_x u + f_y v + f_t)^2 + l(u_x^2 + u_y^2 + v_x^2 + v_y^2)$$

Iterative solution

$$u(i,j)=0,\ v(i,j)=0,\ \text{for all } i, j$$



ALGORITHM FOR DYNAMIC IMAGE PAIRS

1- Initialize velocity vectors c(i,j)=0 for all (i,j)

2- Let k denote the number of iterations. Compute u^k, v^k, for all pixels (i,j):

$$u^k(i,j) = \bar{u}^{k-1}(i,j) - f_x(i,j)\frac{P(i,j)}{D(i,j)}$$

$$v^k(i,j) = \bar{v}^{k-1}(i,j) - f_y(i,j)\frac{P(i,j)}{D(i,j)}$$

The partial derivatives f_x, f_y, f_t can be estimated from the pair of consecutive images.

3- Stop if:

Where ε is the maximum permitted error; return to step 2 otherwise

ALGORITHM FOR IMAGE SEQUENCE

1- Evaluate starting values of the optical flow c(i,j) for all (i,j)

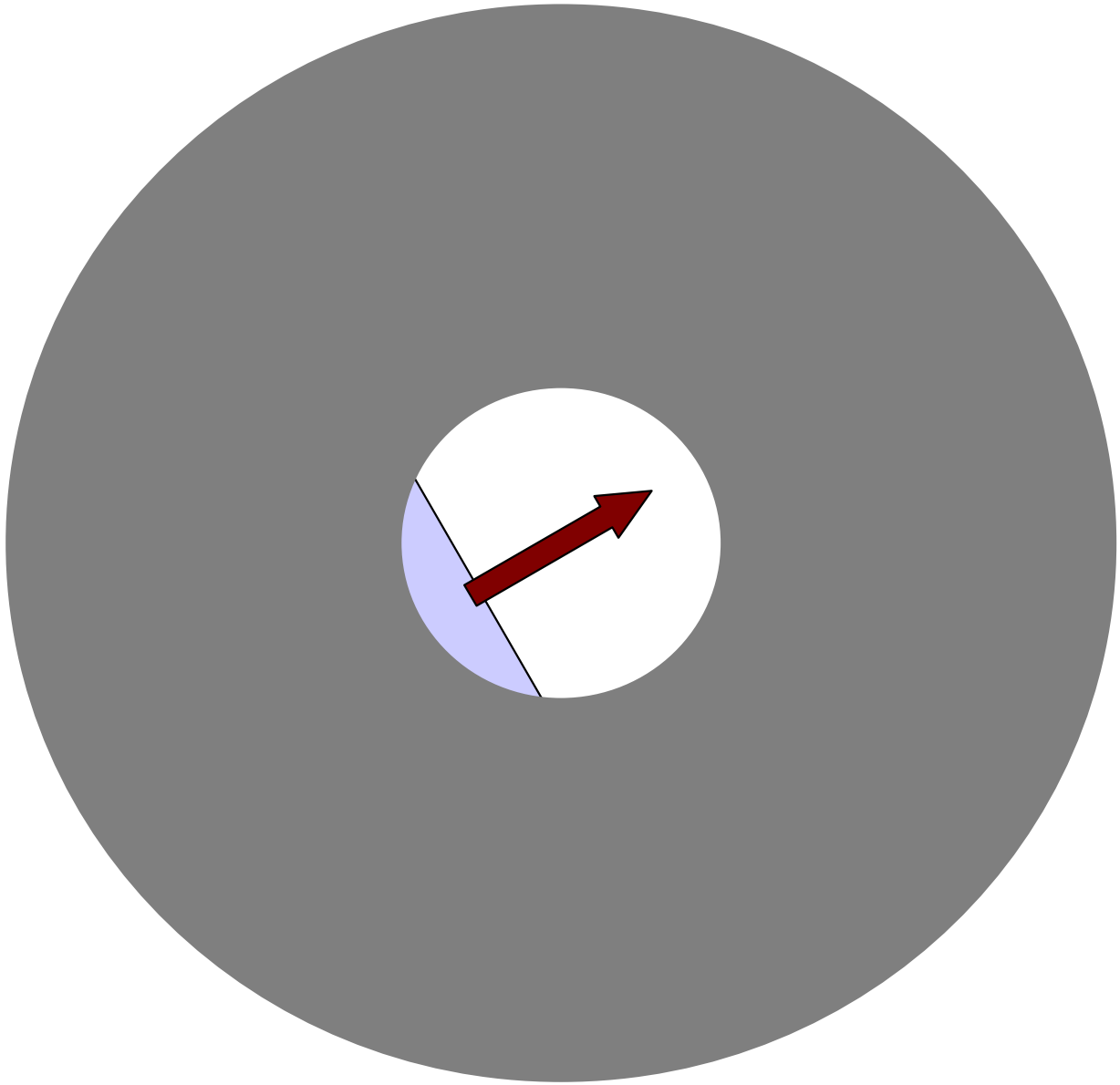
2- Let m denote the sequence number of the currently processed image. For all pixels (i,j) of the next image, evaluate:

$$u^{m+1}(i,j) = \bar{u}^{m}(i,j) - f_x(i,j)\frac{P(i,j)}{D(i,j)}$$

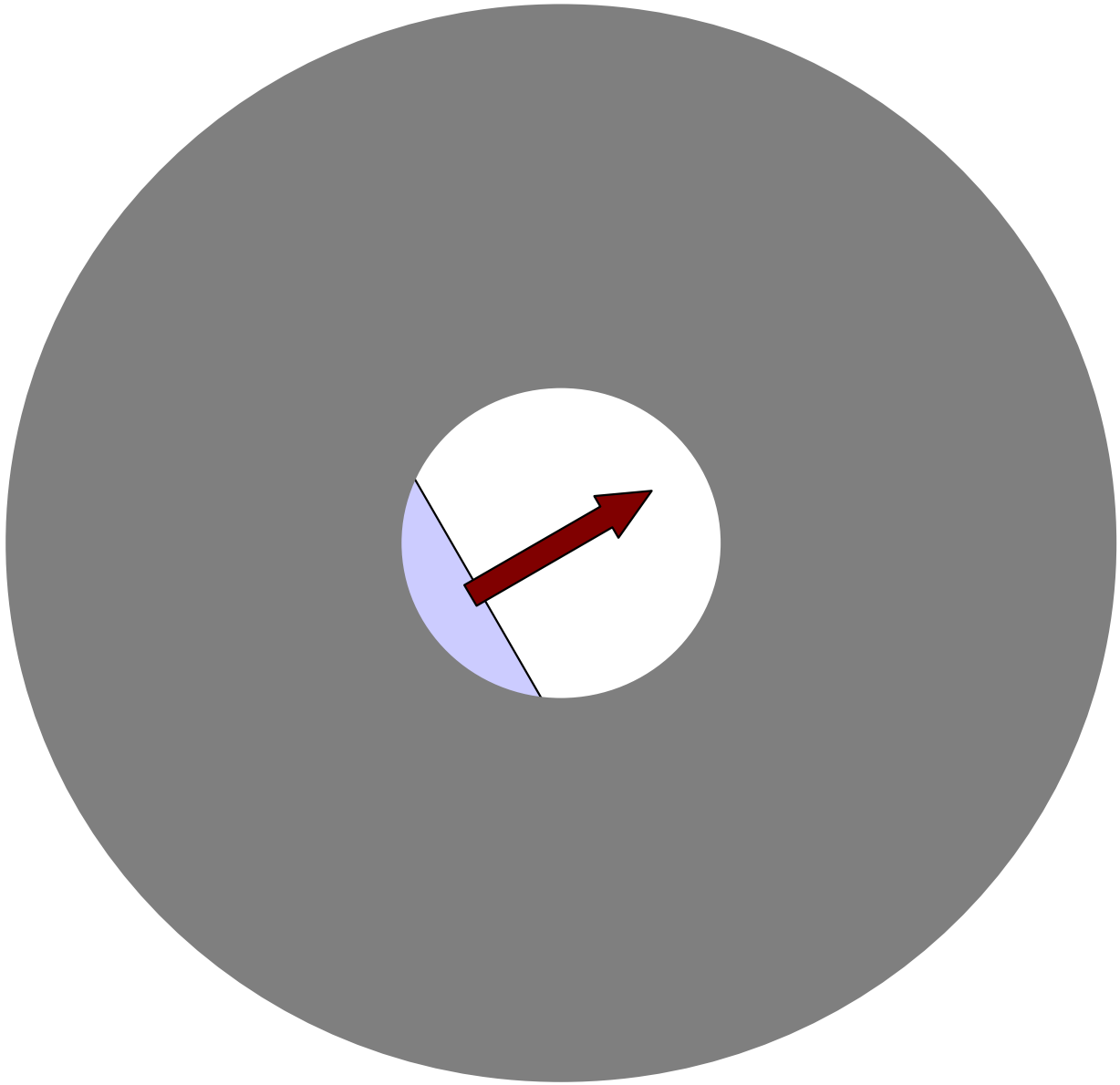
$$v^{m+1}(i,j) = \bar{v}^{m}(i,j) - f_y(i,j)\frac{P(i,j)}{D(i,j)}$$

3- Repeat step 2 to process all images in the sequence

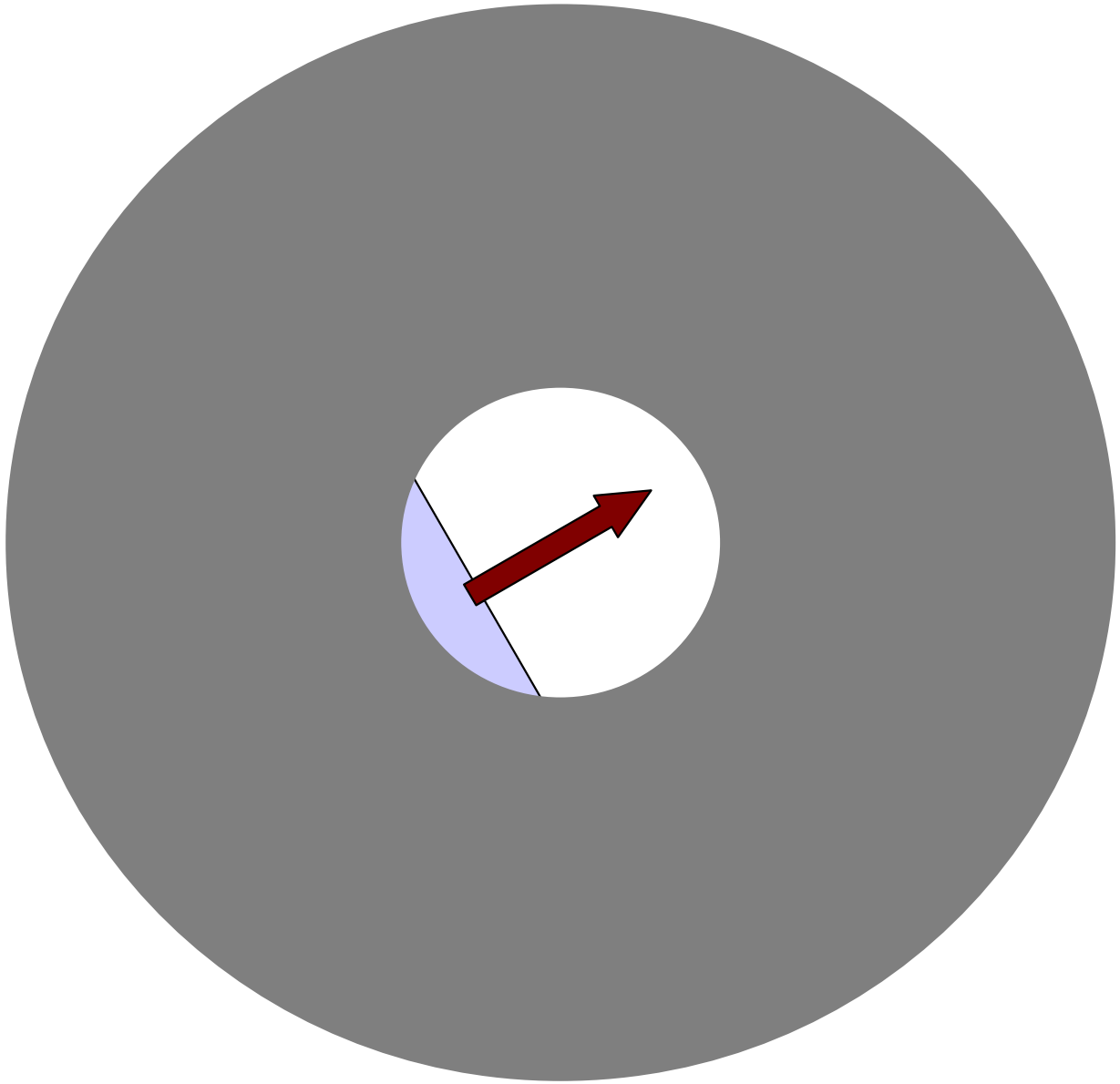
The Aperture Problem



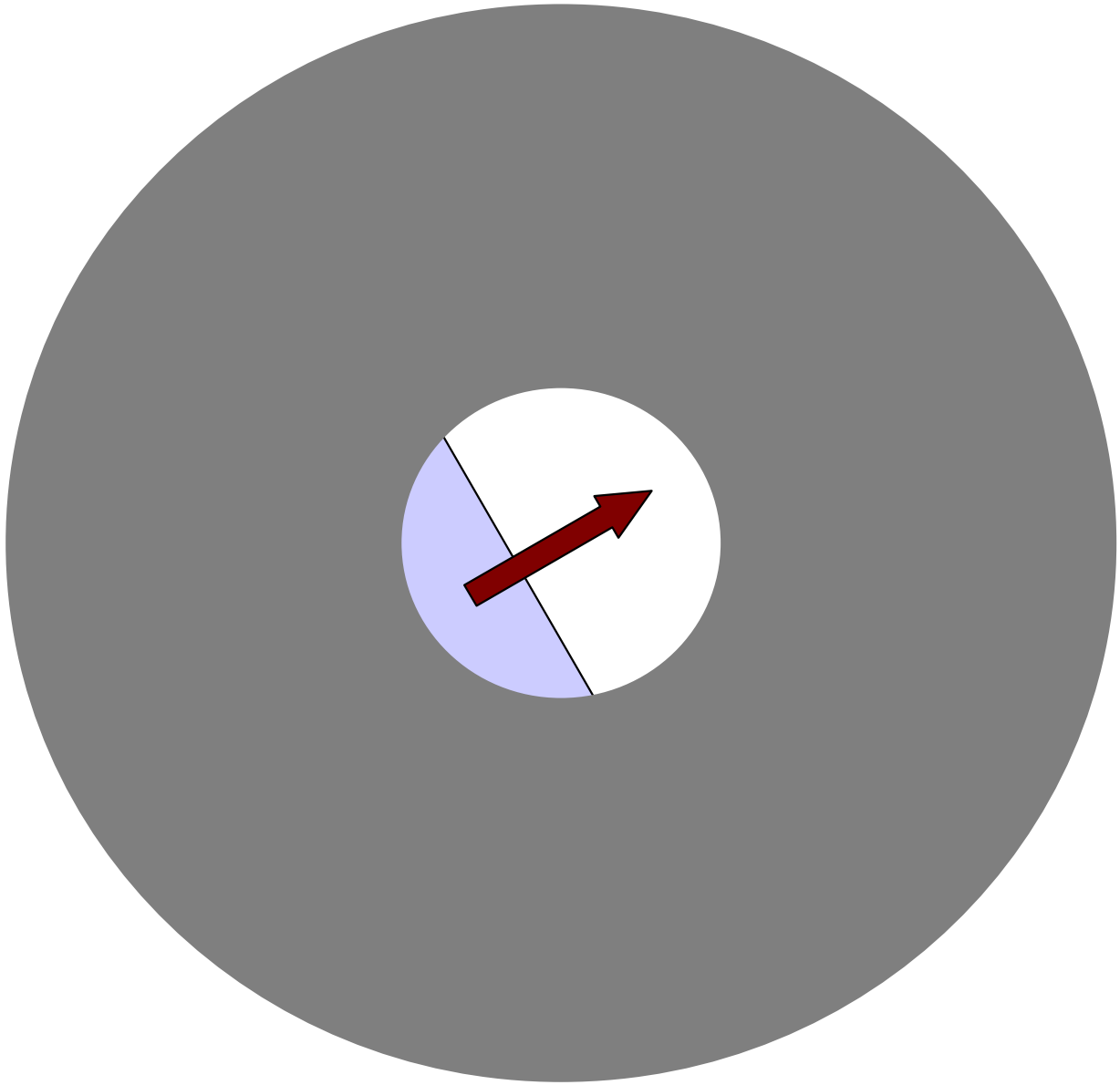
The Aperture Problem



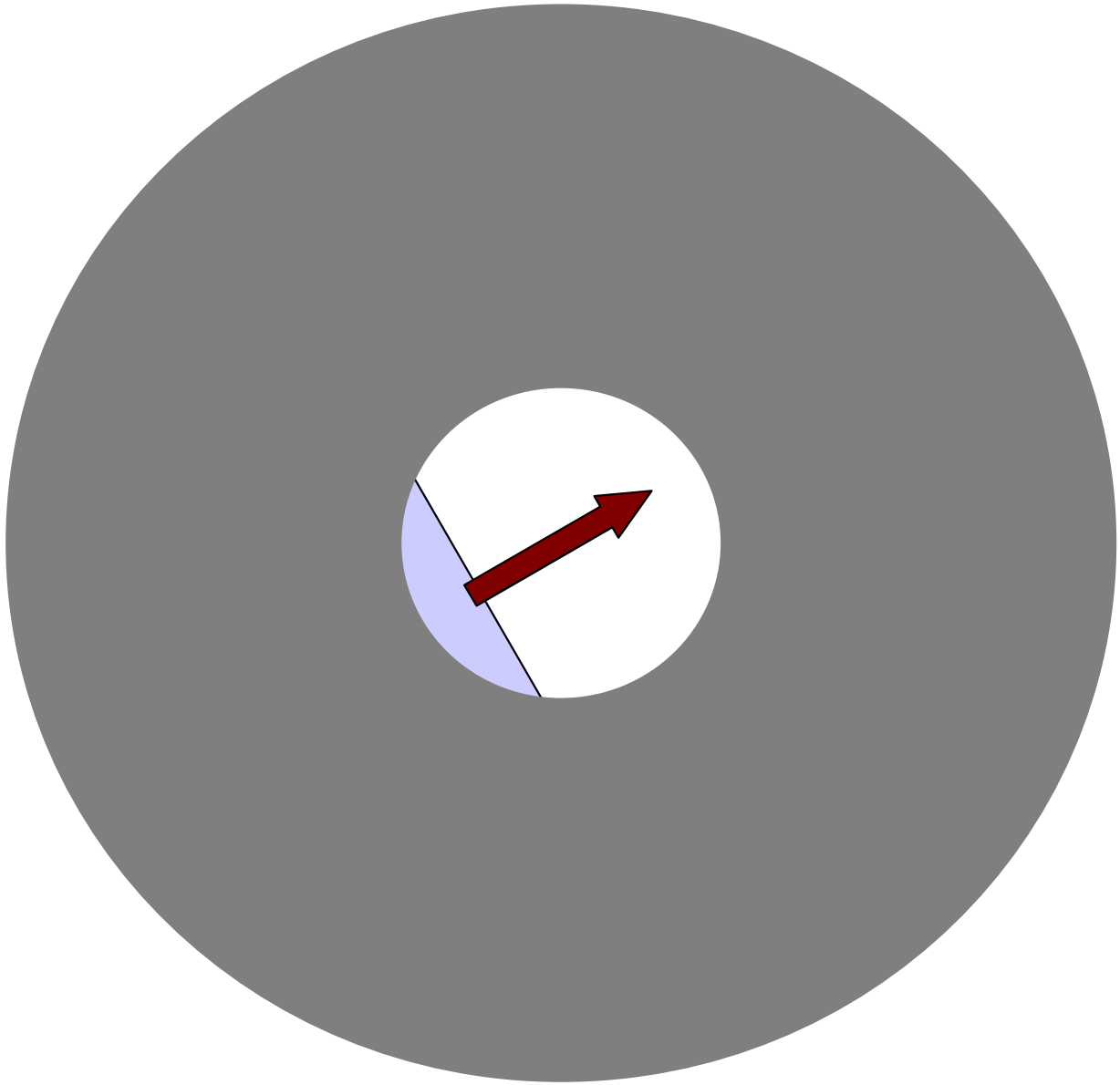
The Aperture Problem



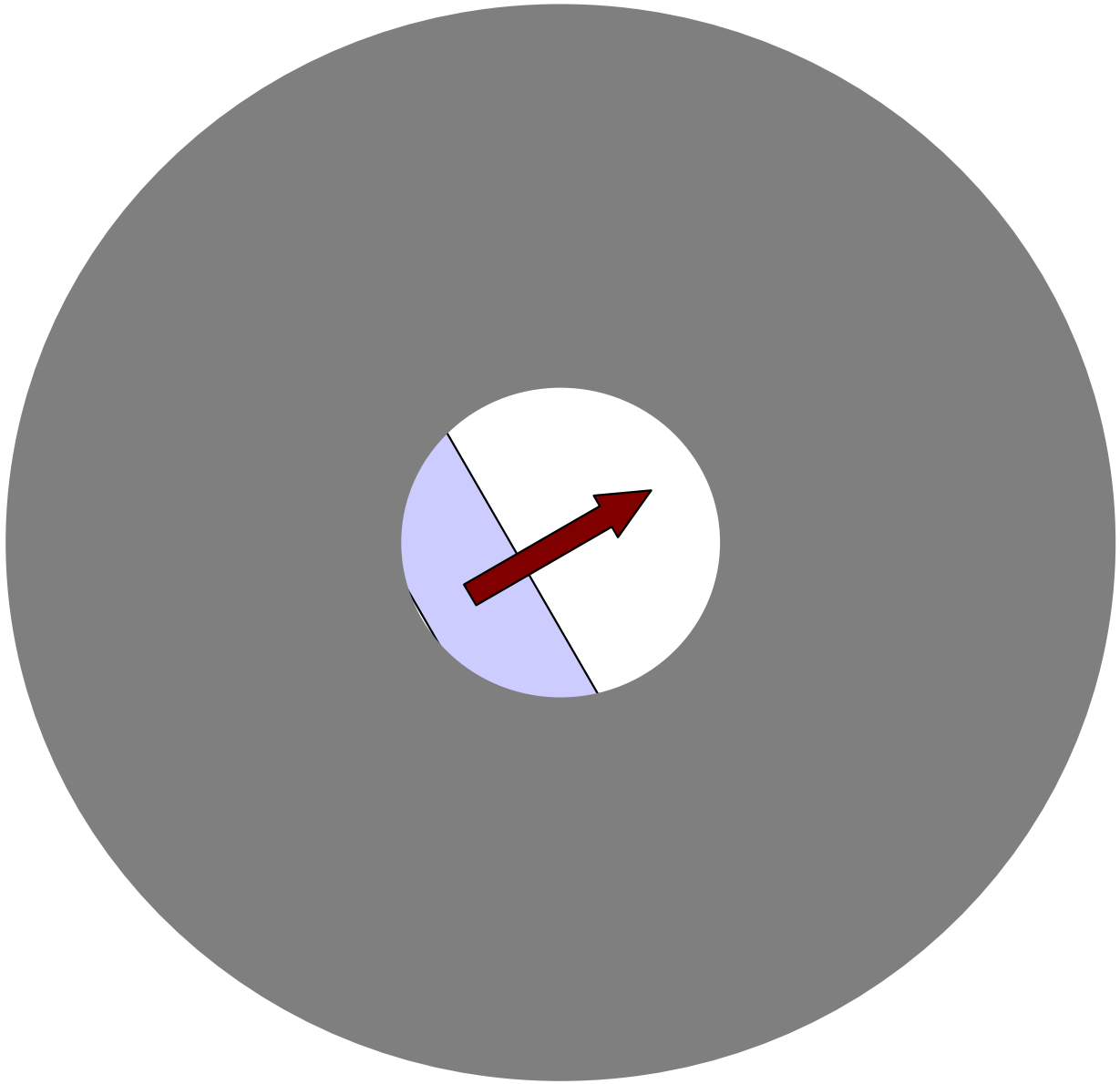
The Aperture Problem

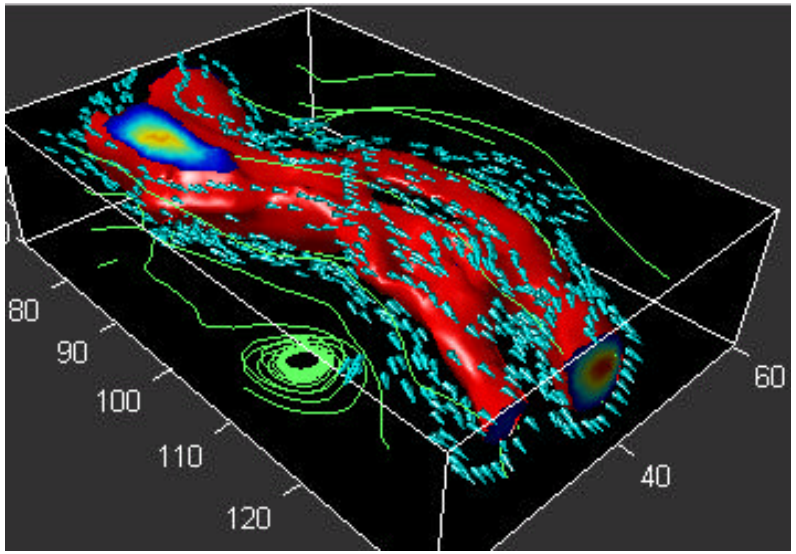


The Aperture Problem



The Aperture Problem

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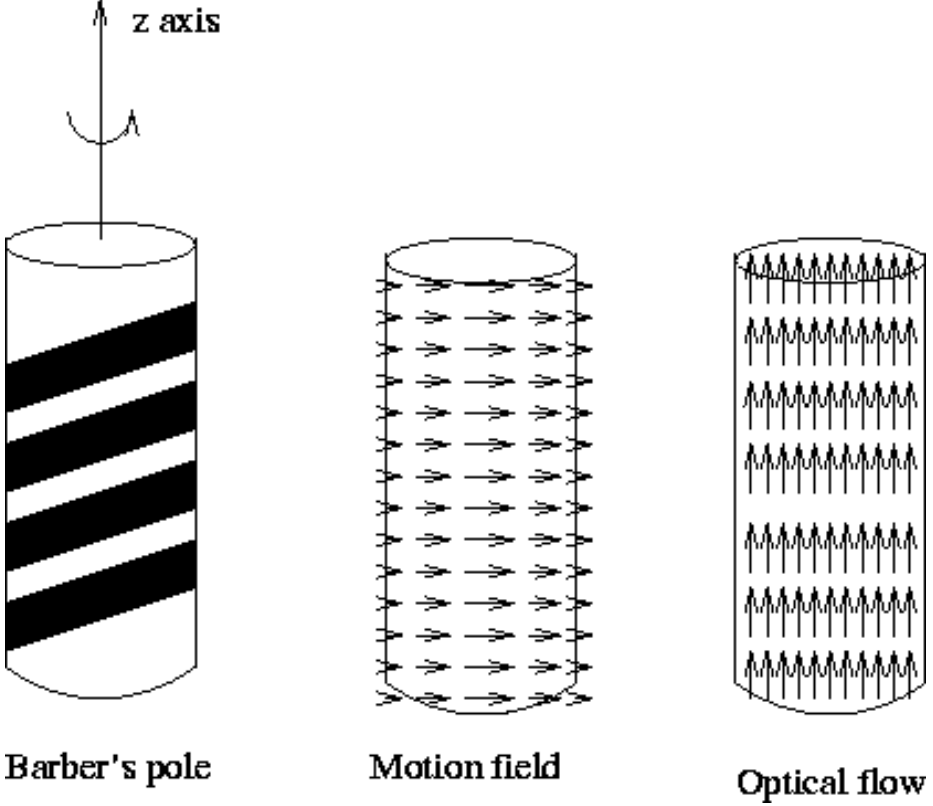
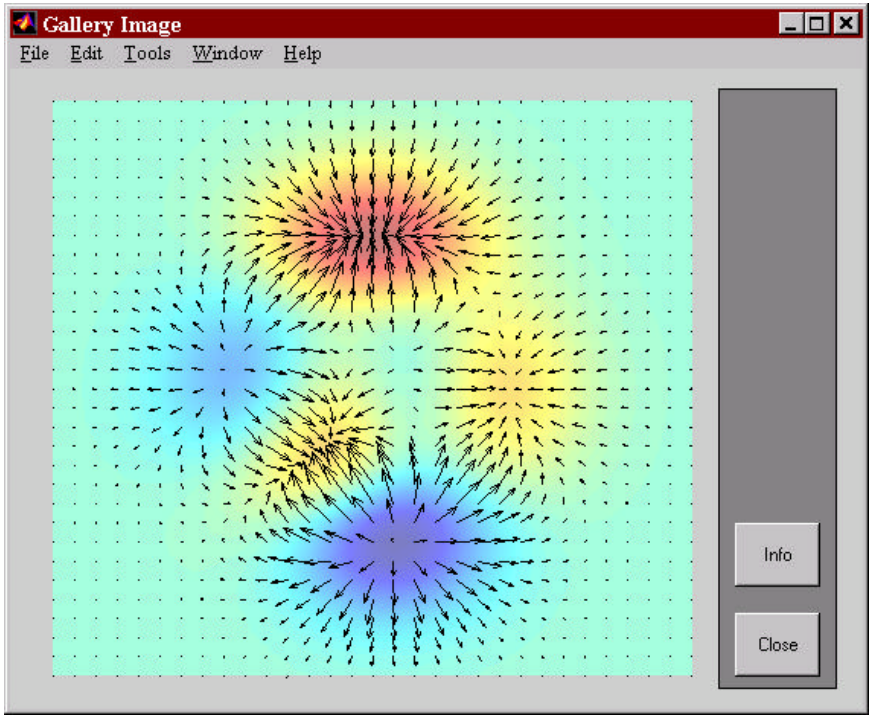

z axis
Barber's pole
Motion field
Optical flow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And now some practising...