Reconstructing 3-D Blood Vessel Shapes from Multiple X-Ray Images

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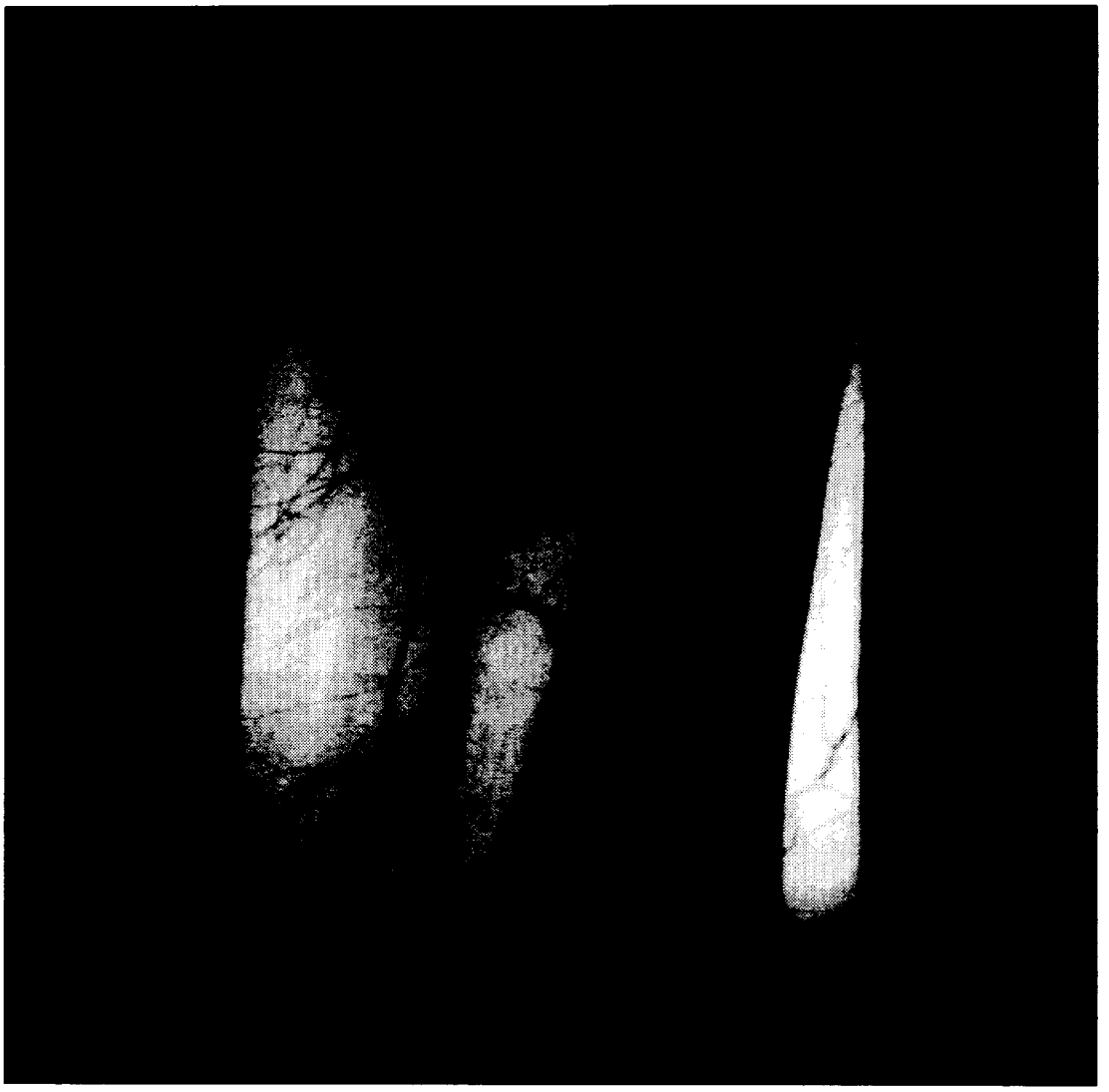
Angiograms

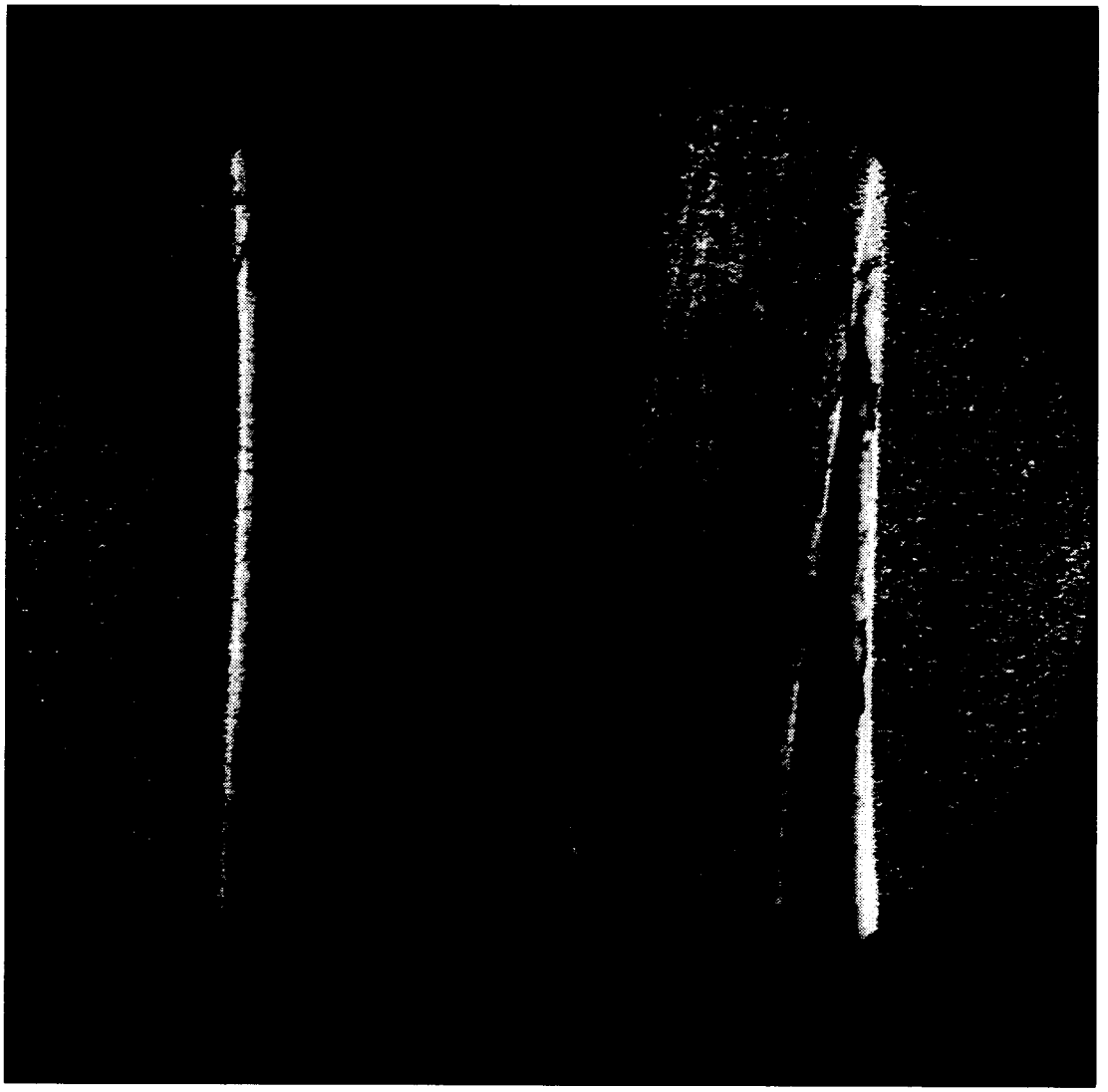
Digital x-ray images takens with an opaque contrast agent injected into the vessels.

Thigh:



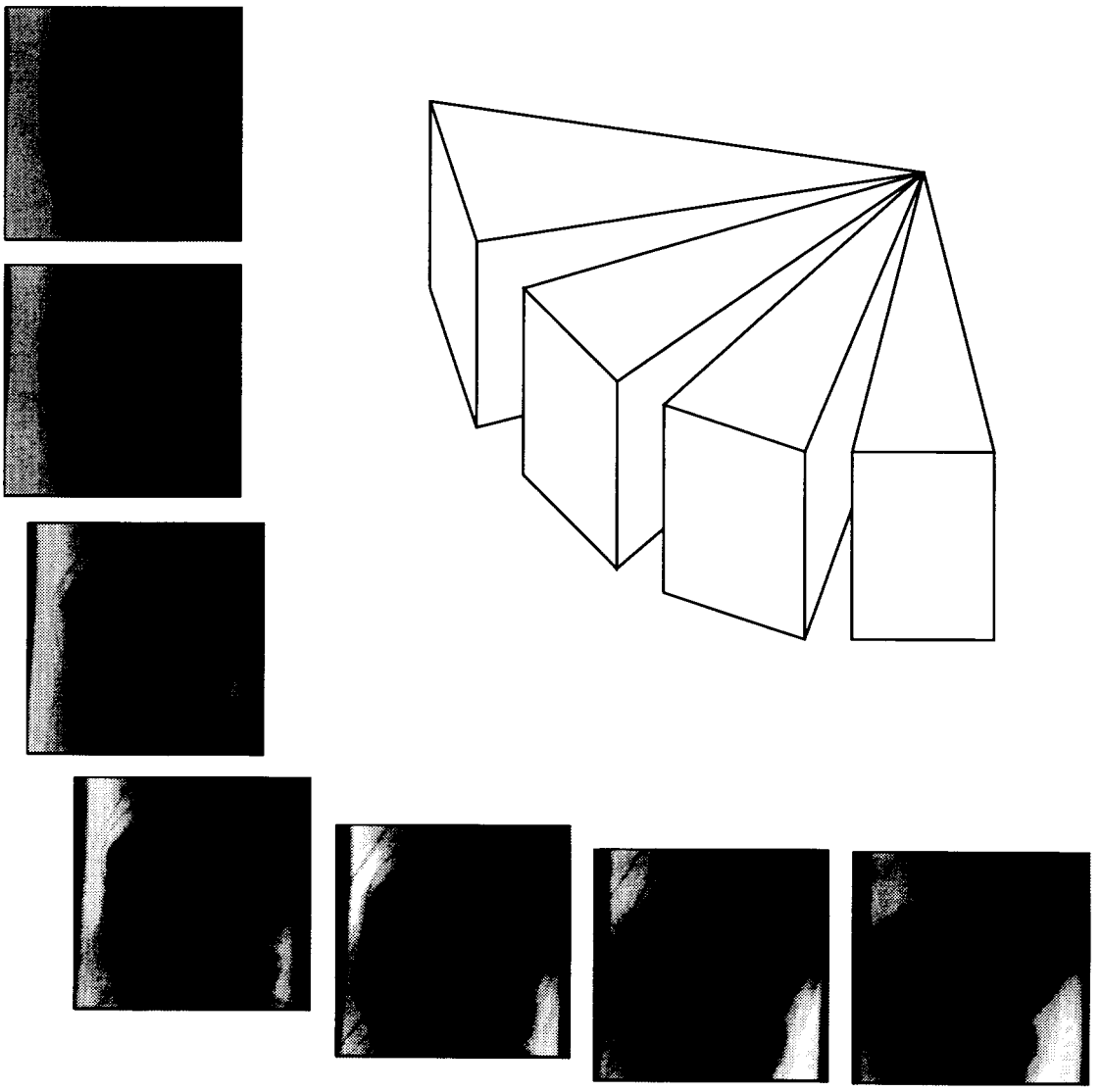
Subtracted Angiograms

Subtracting an image without contrast agent improves contrast:



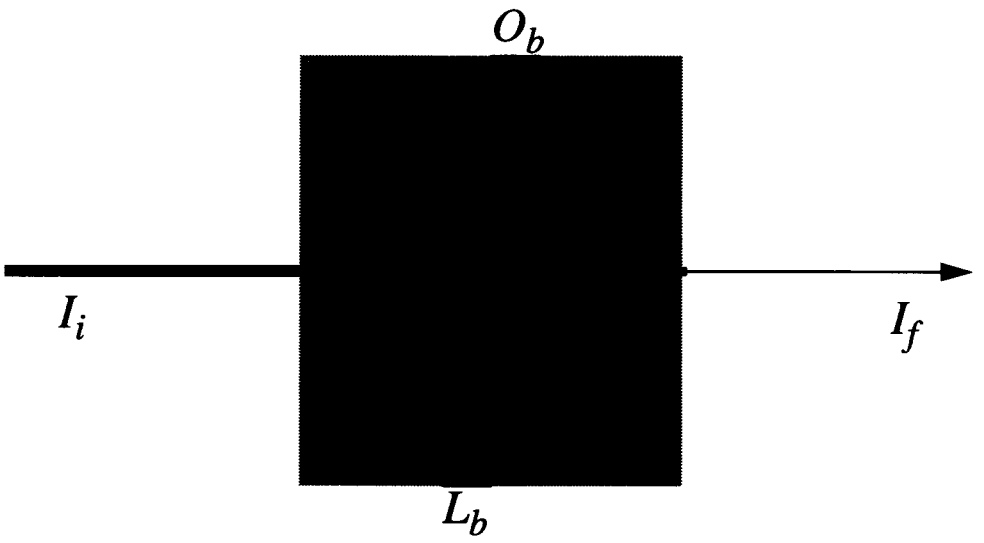
Camera Positions

Knee:



Finding Vessels in Single Images

X-ray beam's intensity is diminished fractionally by the tissues it passes through:



$$I_f = I_i O_a^{L_a} O_b^{L_b} O_c^{L_c}$$

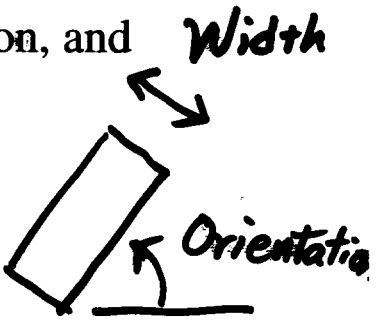
$$\log I_f = \log I_i + L_a \log O_a + L_b \log O_b + L_c \log O_c$$

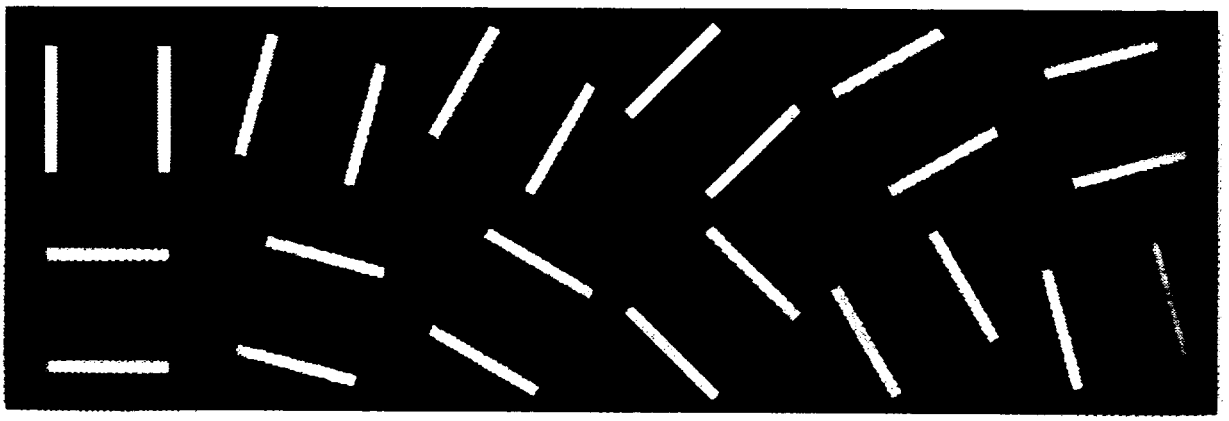
The decrease in log intensity is linearly proportional to the amount of tissue passed through.

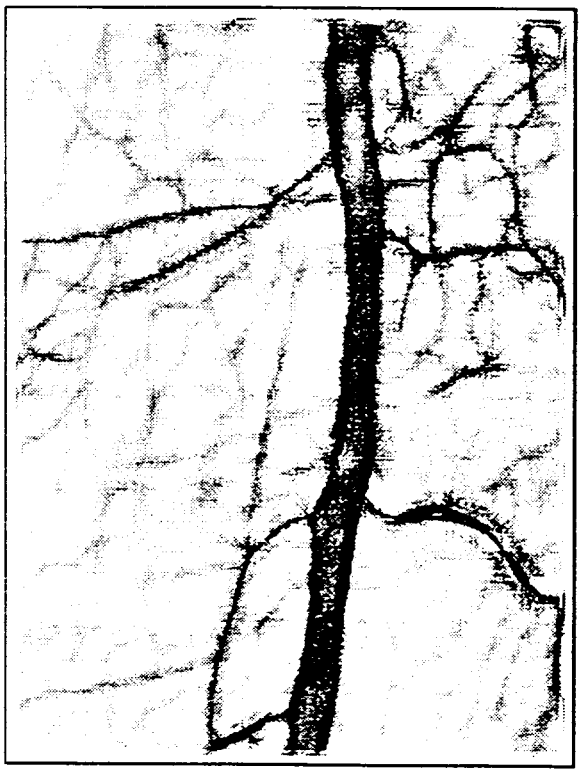
Finding Vessels in Single Images

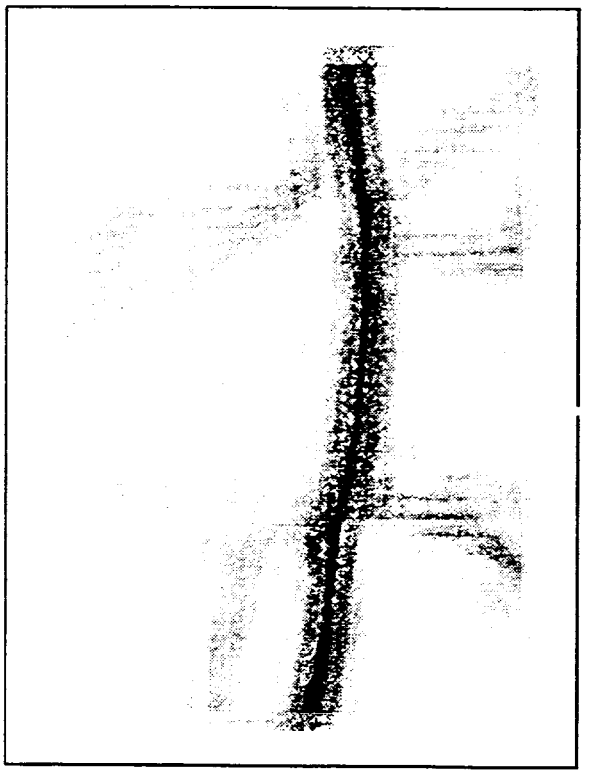
Darkness of vessel (Chaudhuri, Chatterjee, Katz, Nelson, and Goldbaum, 1989):

$$2\,(\log O)\,\sqrt{r^2 - x^2}$$





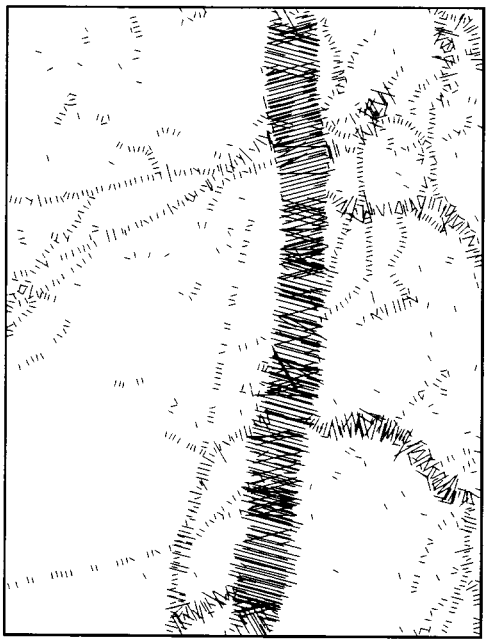




Finding Vessels in Single Images

Magnitude of filter responses:

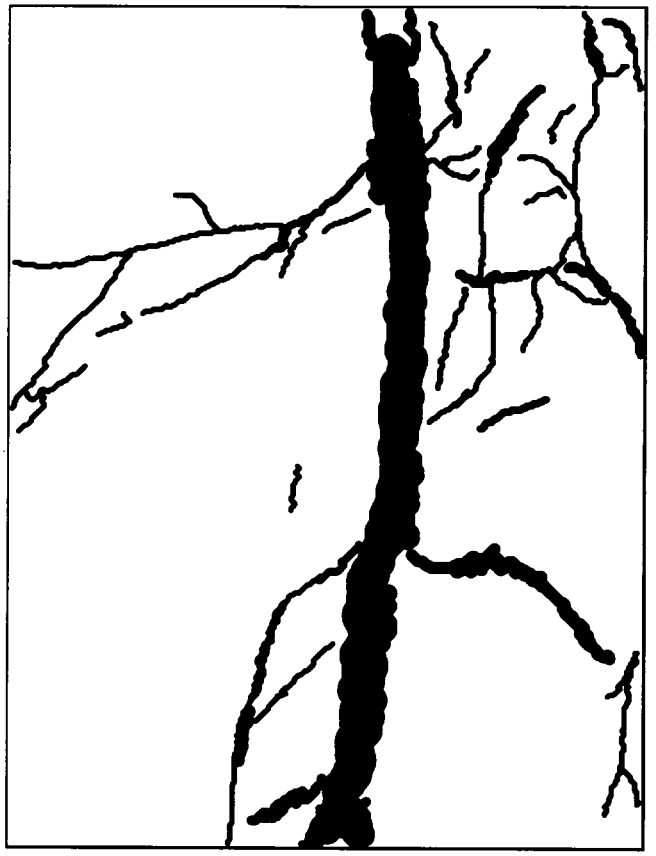
Width/angle of filters with highest response:



Finding Vessels in Single Images

Edge linker (Gonzalez and Woods, 1992):

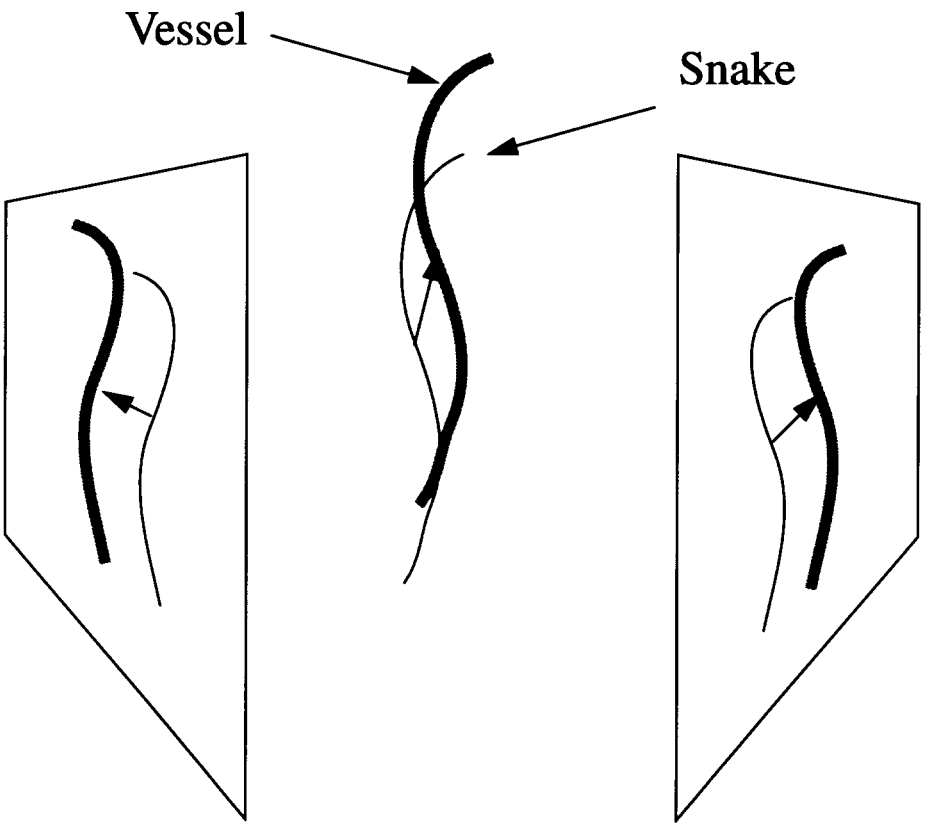
- Extend in the direction of the vessel
- Add pixels whose width matches edge so far
- Extend edges with fewer gaps



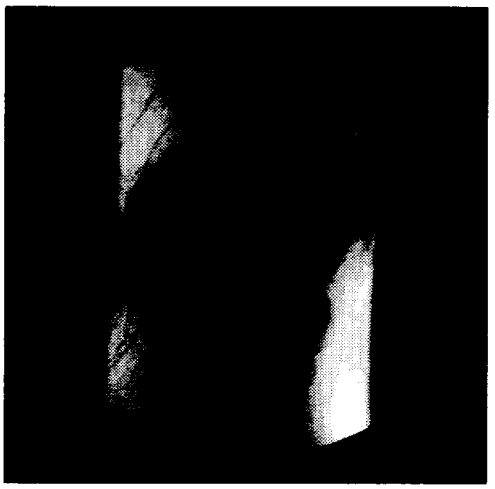
Locating Vessels in 3-D

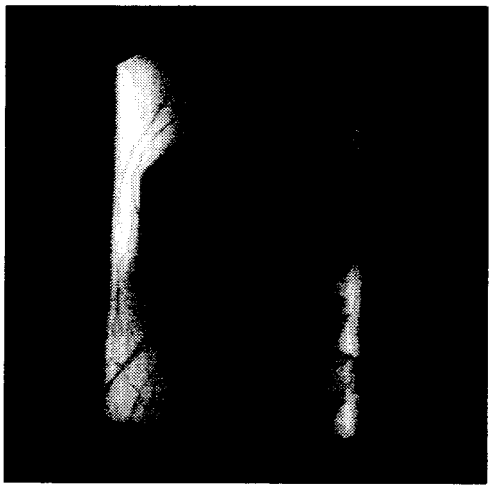
Snakes (Kass, Witken, and Terzopoulos, 1987):

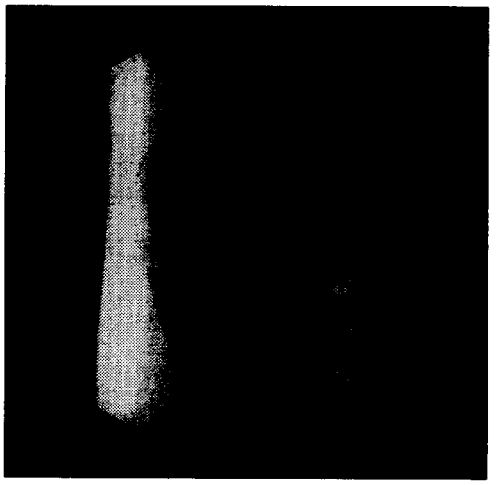
- Internal forces due to stretching and bending
- External forces from multiple images



3-D Location of Vessels in Knee

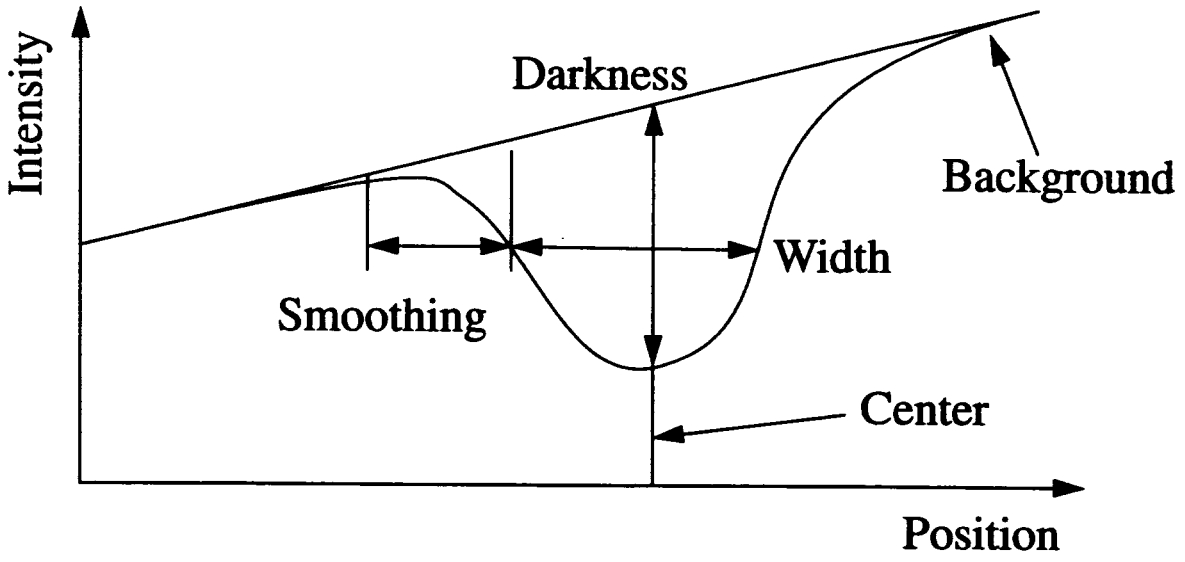


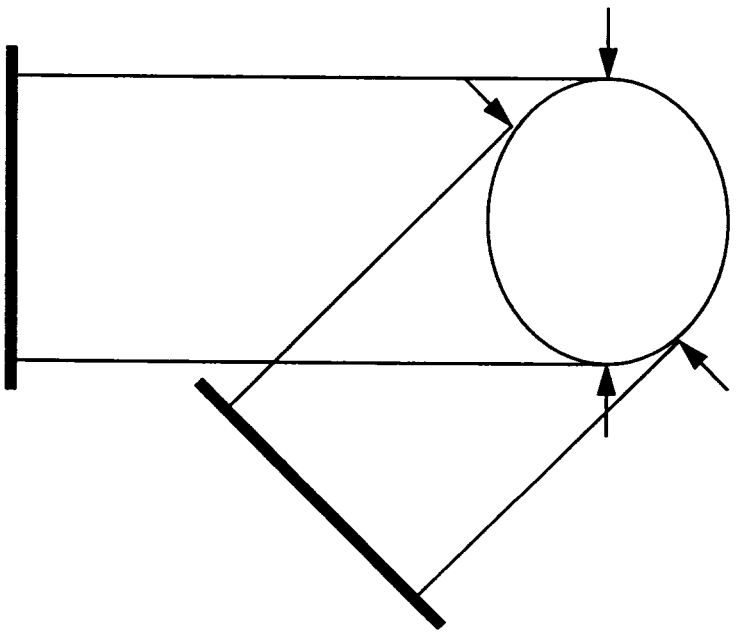




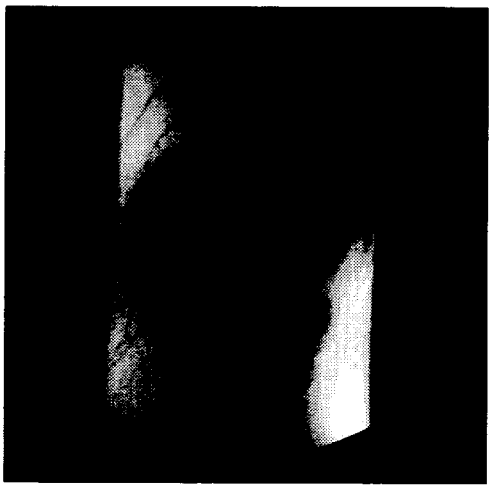
Measuring Vessel Diameters

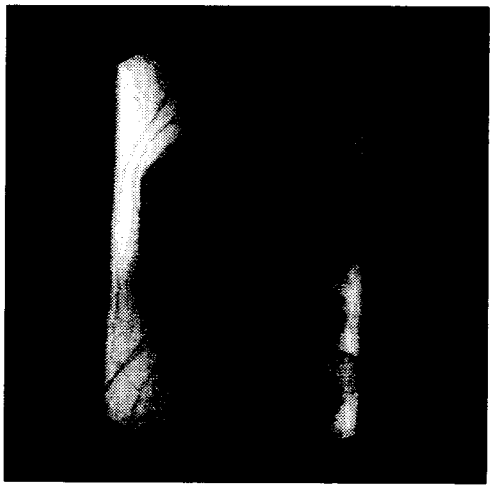
Intensity profile model (Kitamuro, Tobis, and Sklansky, 1988):

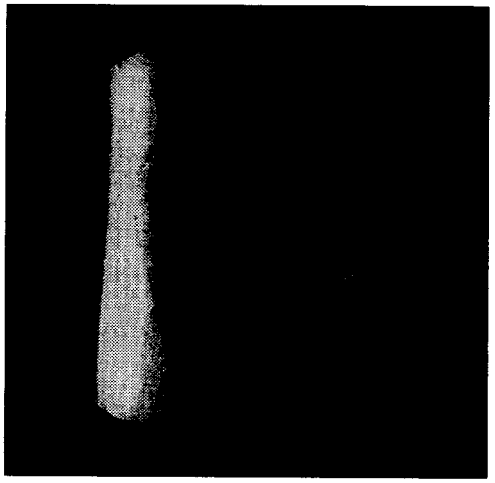




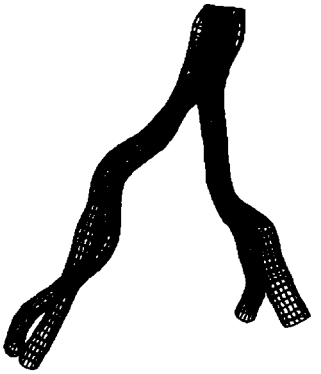
Reconstructed Arteries in Knee

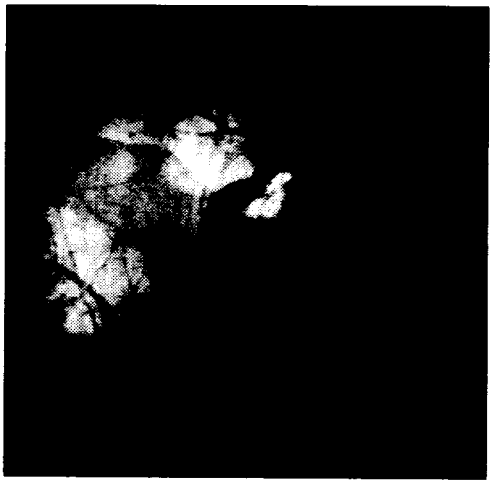


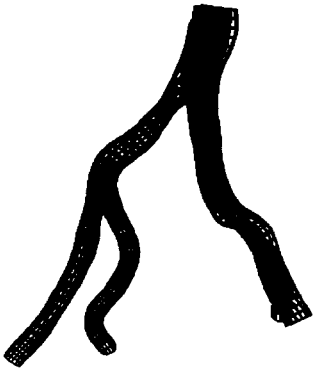




Reconstructed Arteries in Pelvis







Conclusions and Future Work

- Successfully applied to three sets of angiogram images
  - Reconstructed the main vessels
  - Reconstructed main constrictions

- Future work to:
  - Automate initial placement of snakes
  - Remove assumption of orthographic projection