3.2 ACTIVE CONTOUR MODELS

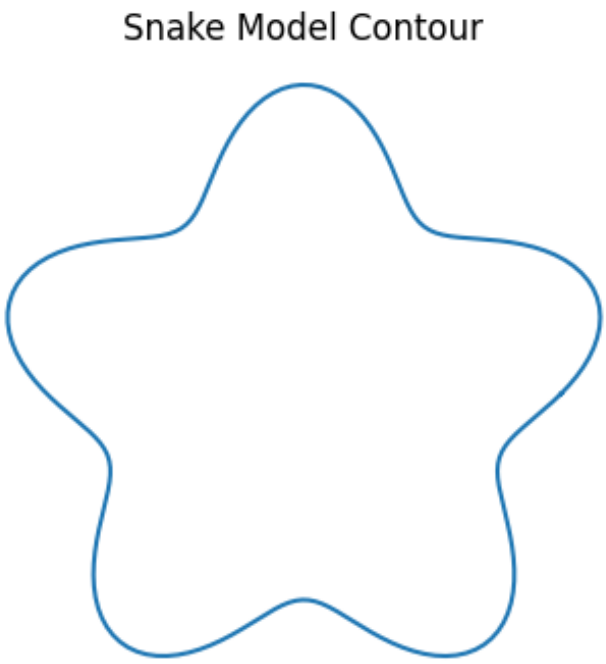
Active Contour Models are important techniques in image processing and computer vision. These models are mainly used for object boundary detection and image segmentation. The contour or curve automatically moves toward the object boundary by minimizing energy. The three major active contour models are Snake Model, Gradient Vector Flow (GVF) Model, and Balloon Model.

1. Snake Model

The Snake Model is the classical active contour model introduced for detecting object boundaries. A snake is a flexible curve placed near the object in an image. The curve changes its shape gradually until it fits the object boundary accurately. The movement of the snake depends on energy minimization. Two major forces act on the snake. Internal forces maintain smoothness and continuity, while external forces pull the snake toward edges and lines in the image.

The total energy of the snake is given by:
Total Energy = Internal Energy + External Energy

Internal energy contains elasticity and rigidity. Elasticity controls stretching, and rigidity controls smooth bending of the curve. External energy is derived from image gradients and becomes stronger near edges.



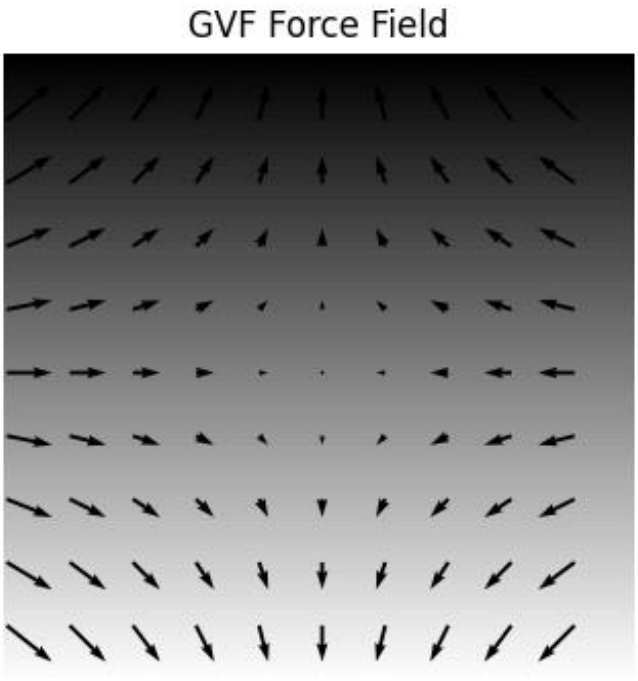
2. Gradient Vector Flow (GVF) Model

The Gradient Vector Flow (GVF) Model is an improved version of the snake model. Classical snakes have limitations such as small capture range and poor detection of concave boundaries. GVF solves these problems by creating a vector force field over the entire image.

The GVF force field directs the contour toward object boundaries even when the initial contour is placed far away from the object. It also allows the contour to enter deep concave regions. This makes GVF more robust and accurate in segmentation tasks.

Advantages of GVF include:

- Large capture range
- Better concave boundary detection
- Less sensitivity to initialization
- Improved segmentation accuracy



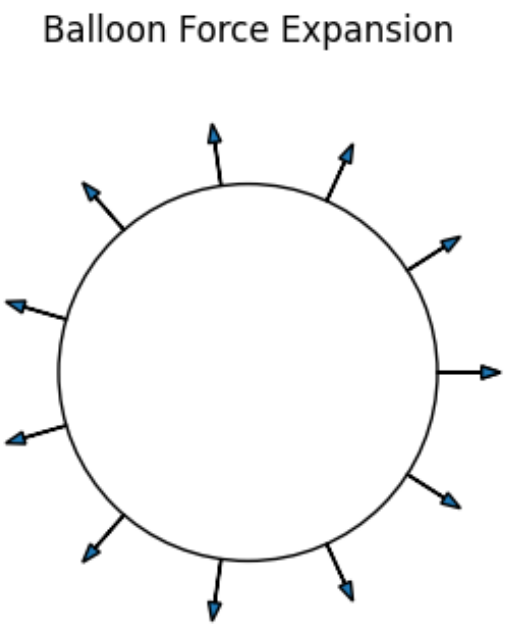
3. Balloon Model

The Balloon Model is an extension of the snake model that introduces an additional pressure force. This force behaves like air pressure inside a balloon and pushes the contour outward or inward. The balloon force helps the contour move quickly toward object boundaries.

Initially, the contour is placed inside or outside the object. The pressure force expands or shrinks the contour, while image forces stop the movement at strong edges. Internal forces maintain smoothness and continuity.

Advantages of the Balloon Model include:

- Faster convergence
- Better handling of weak edges
- Reduced sensitivity to initialization



4. Applications and Conclusion

Active contour models are widely used in medical image analysis, object tracking, face recognition, shape analysis, and computer vision systems. In medical imaging, these models help detect tumors and organ boundaries accurately. In surveillance systems, they are useful for tracking moving objects.

Among the different models, the GVF model provides the best accuracy and performance because of its ability to detect concave boundaries and work with distant initial contours. However, the choice of model depends on the application requirements and computational complexity.