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Particle Based Image Segmentation with Simulated Annealing

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1. Charged Particle Model

- Charged Particle Model: image segmentation method by Jalba et al. [1] inspired by classical electrostatics.
- Two stages
  1. Simulation of charged particles moving in an electric field generated from the input image.
  2. Construction of a shape (curve or surface) from particle positions.
- Particles are attracted to edges in the input image.
- Particles repel each other.
- CPM searches for a low energy configuration of the particles.

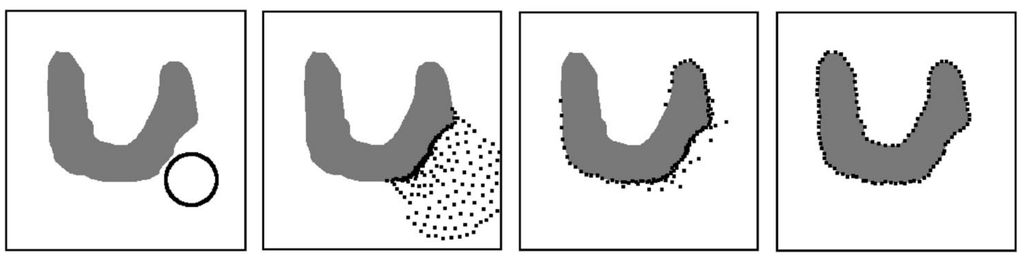


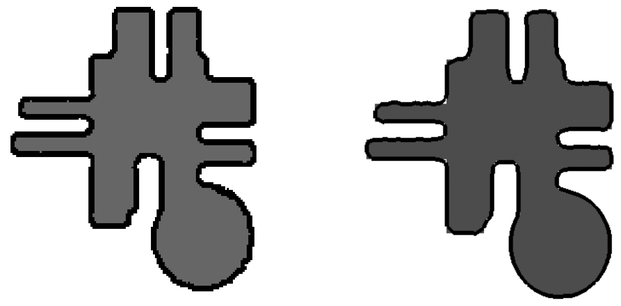
Figure 1: *Illustration of CPM. Particles move from their initial positions to the edges of the input image.*

2. Alternative: Simulated Annealing for positioning the particles

- CPM minimizes an energy functional by integrating Newton's equation over time.
- Can be reformulated as a *combinatorial optimization problem*.
- As an alternative, the solution can be approximated by a stochastic method, *simulated annealing* (SA).
- Motivation
  - Allows various simplifications.
  - Only positions are considered, no velocities.
  - Faster convergence.
  - Ability to look beyond local minima.
- The basic idea of SA is to iteratively:
  - Randomly change the current state of the system.
  - Always accept a new state with a lower energy configuration.
  - Accept a new state with a higher energy configuration with a probability that depends on the *energy difference* and a *temperature parameter* that gradually decreases over time.

3. Results

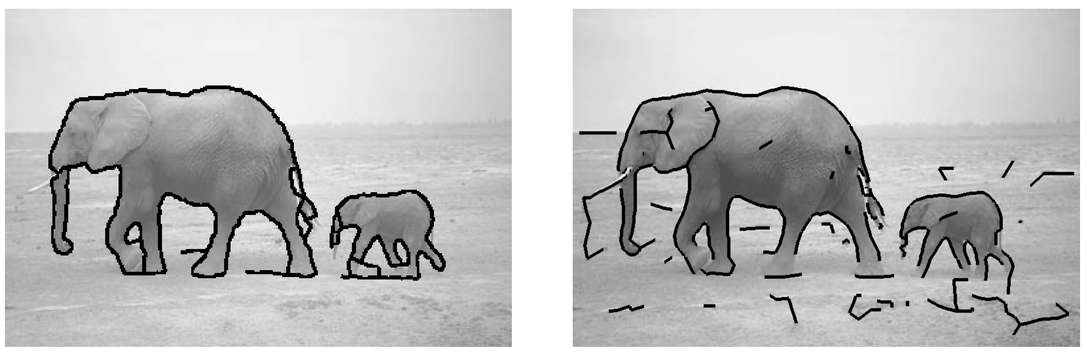
- Results for synthetic images
  - Reconstructed curves are as good as the curves reconstructed by CPM (Figure 2).
- Results for non-synthetic images
  - Results differ from CPM's results, but are still similar.
  - CPM's results seem better, with more closed curves (Figure 4).
- SA implementation is about twice as fast as CPM (which uses a multi-scale approach).



(a) CPM (b) SA

Figure 2: *The input image, a simple image with concavities, shown together with the constructed curves created with CPM (a) and SA (b).*

Figure 3: *The curve constructed from particles positioned with SA shown together with the input image, a spiral with a deep concavity.*



(a) CPM (b) SA

Figure 4: *CPM and SA applied to a non-synthetic natural image.*

4. Conclusion

- The SA variant of CPM is simpler and faster.
- For images with well defined edges, the results are similar, if not better.
- For natural, non-synthetic images, the results are different.
- We will explore whether combining SA with a multi-scale approach (like CPM does) could yield better results.

References

[1] *CPM: A Deformable Model for Shape Recovery and Segmentation Based on Charged Particles. IEEE Trans. Pattern Anal. Mach. Intell.* 26(10):1320–1335, 2004.

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