CS664 Lecture #13: EM algorithm, slanted surfaces, mutual information

Some material taken from:

- **Ranjith Unnikrishnan & Marc Zinck, CMU**
  http://www.cs.cmu.edu/~ranjith/
- **Stan Birchfield, Clemson**
  http://www.ces.clemson.edu/~stb/research/stereo_multiwaycut/
- **Steve Seitz, University of Washington**
  http://www.cs.washington.edu/homes/seitz/
- **Aseem Agarwala, University of Washington**
  http://www.cs.washington.edu/homes/aseem

Announcements

- PS 1 due tonight
  - Probably not graded for a while
- Next quiz in one week (Thursday 10/13)
- Who in 664 is working on the CU-UAV (submarine) project?

Recap

- Many cool applications of pixel labeling problems
  - In graphics
    - Such as graph cut textures, photomontage, etc.
  - In medical imaging
    - Faster MR reconstruction
  - In vision
    - Stereo (regular, multicamera, sloped surfaces)

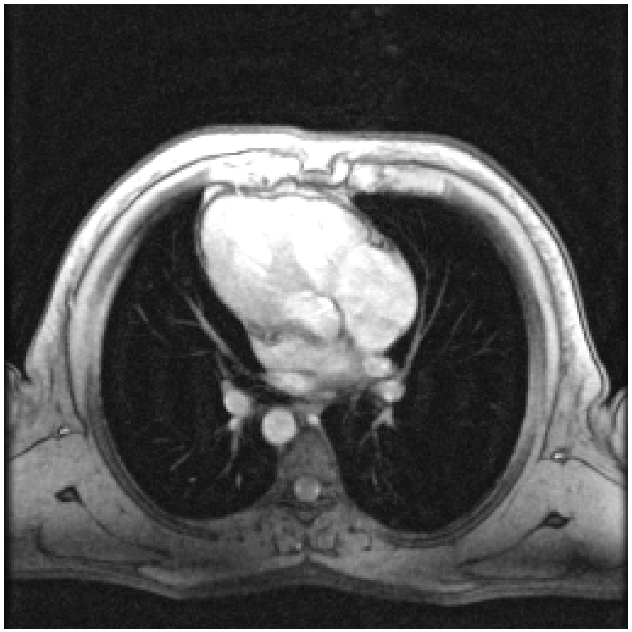
Another SIGGRAPH example

Panoramic video textures (Agarwala *et al.*, SIGGRAPH05)

Another PVT demo

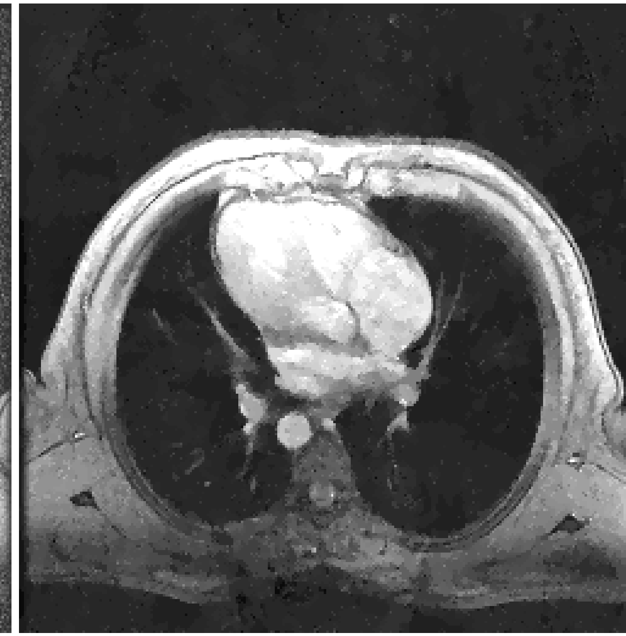
More MR examples

Strongest evidence to date

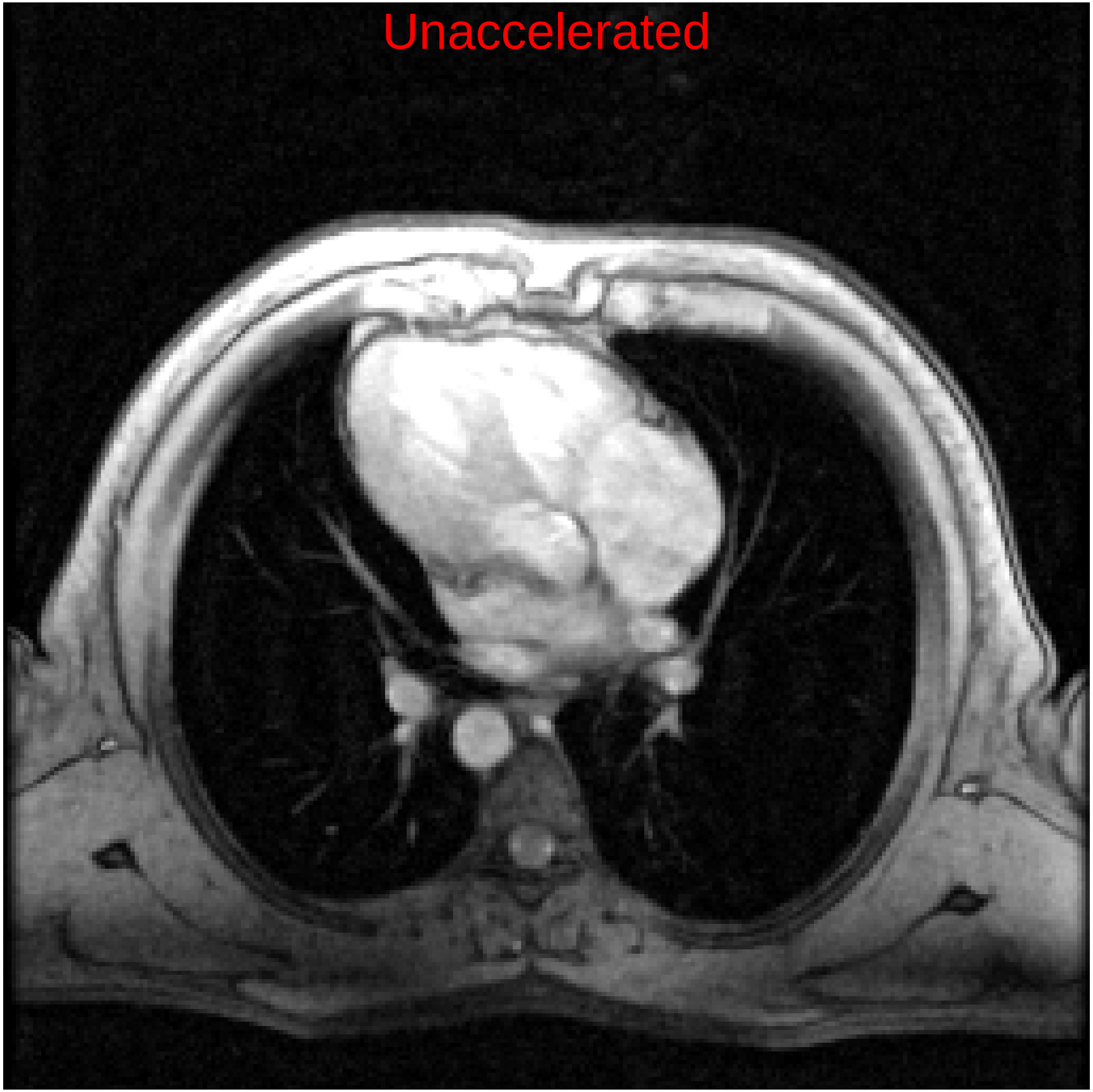


Unaccelerated image

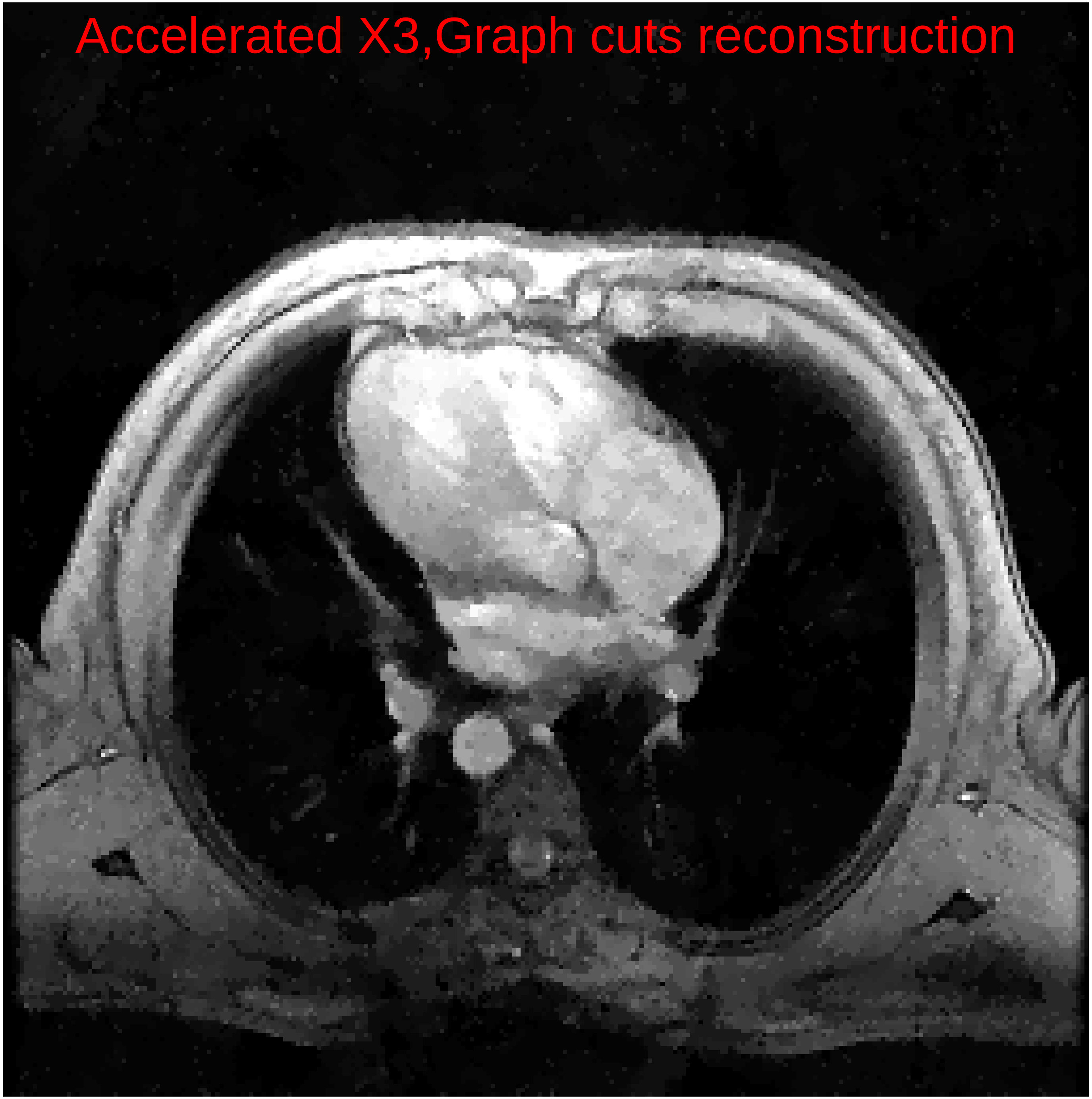
Accelerated X3,
SENSE reconstruction

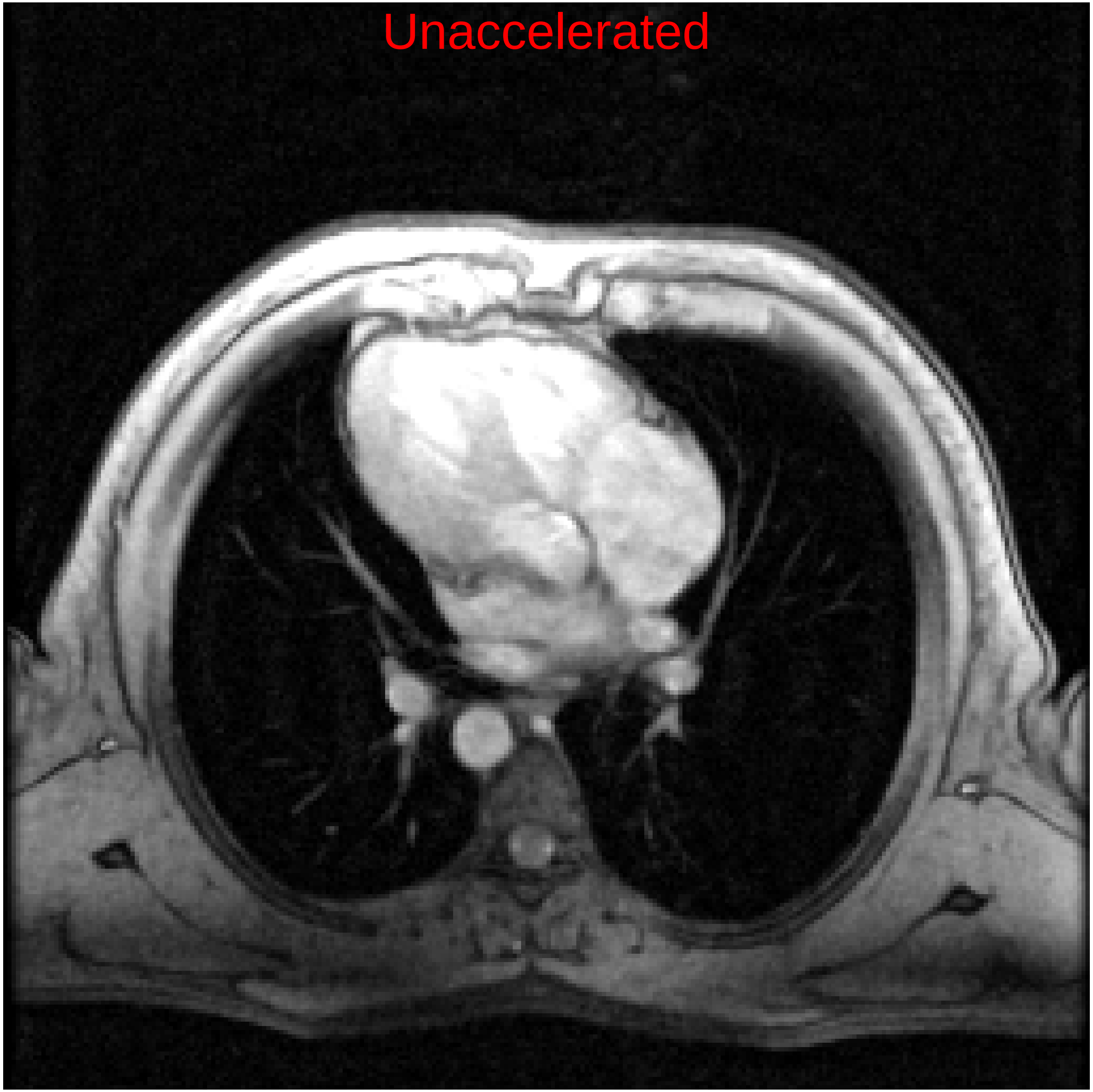


Accelerated X3,
Graph cuts reconstruction


Unaccelerated

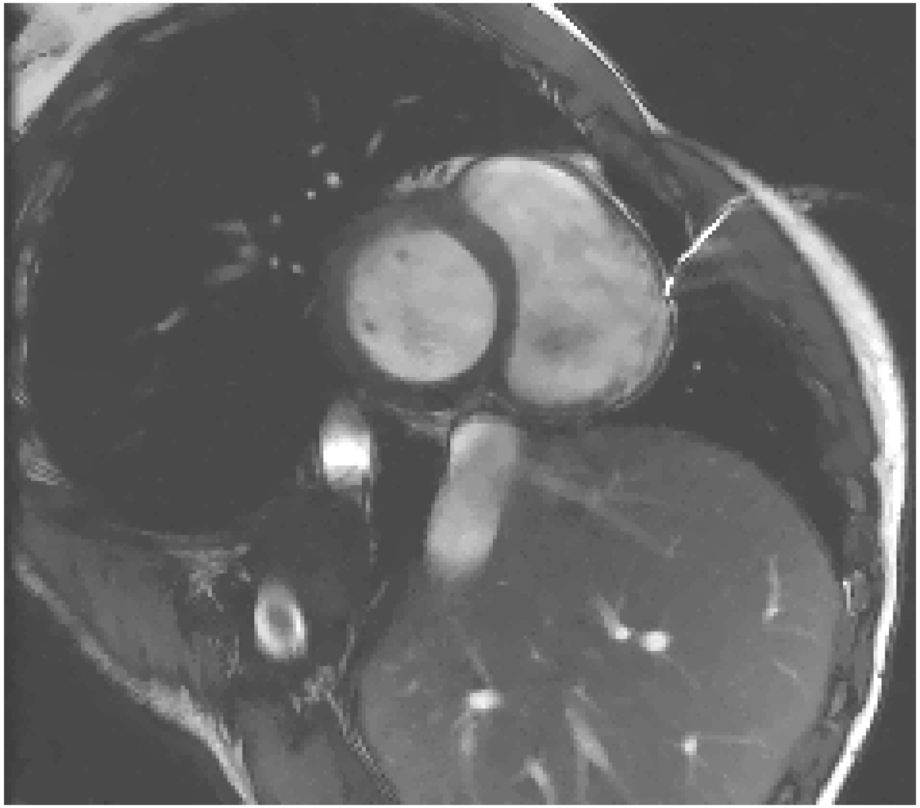

Accelerated X3, SENSE reconstruction


Accelerated X3,Graph cuts reconstruction


Unaccelerated

2-fold acceleration

Unaccelerated



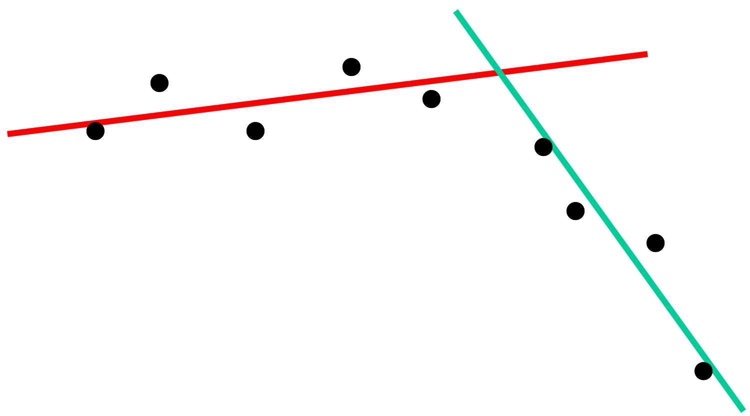
Graph cuts

Back to vision!

- How can we handle situations in stereo like slanted surfaces?
  - Extremely large number of possible planes
  - We can't make each one a label
- What about curved surfaces?
  - Even harder to handle!
- There's an easy way to use graph cuts
- Rely on a powerful technique for vision:
  - Expectation-Maximization (EM) method

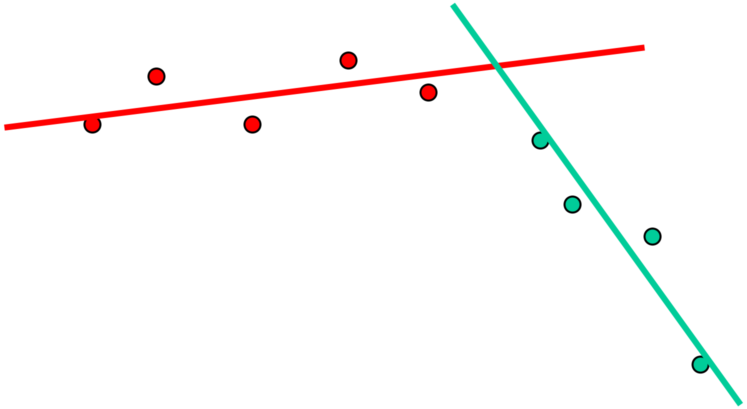
A simple problem – Line fitting

- Goal: To group a bunch of points into two “best-fit” line segments



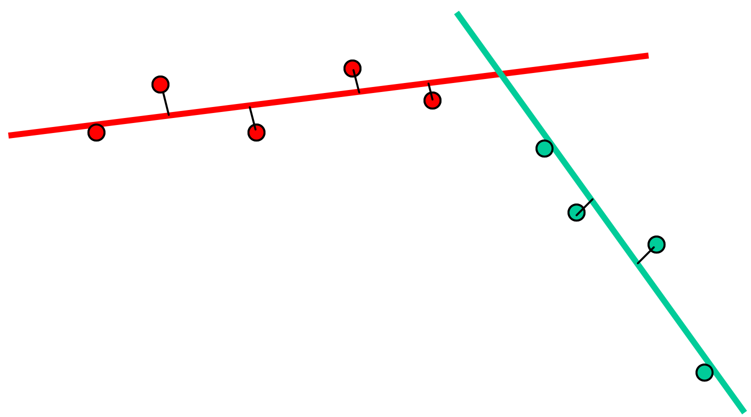
“Chicken-egg problem”

- If we knew which line each point belonged to, we could compute the best-fit lines.



Chicken-egg problem

- If we knew what the two best-fit lines were, we could find out which line each point belonged to.

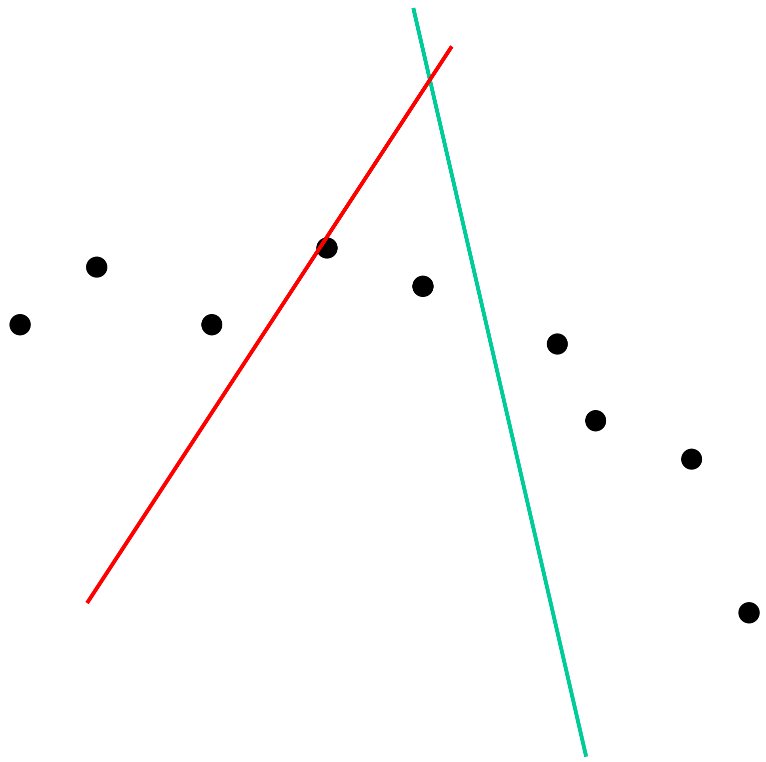


Expectation-Maximization (EM)

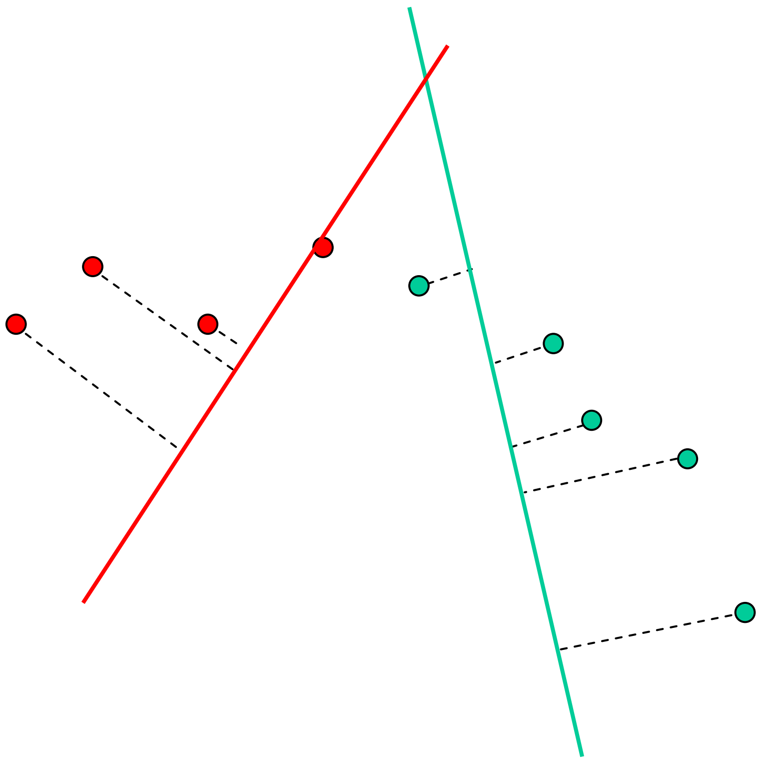
- Initialize: Make random guess for lines
- Repeat:
  - Find the line closest to each point and group into two sets. (Expectation Step)
  - Find the best-fit lines to the two sets (Maximization Step)
  - Iterate until convergence

The algorithm is guaranteed to converge to some local optima

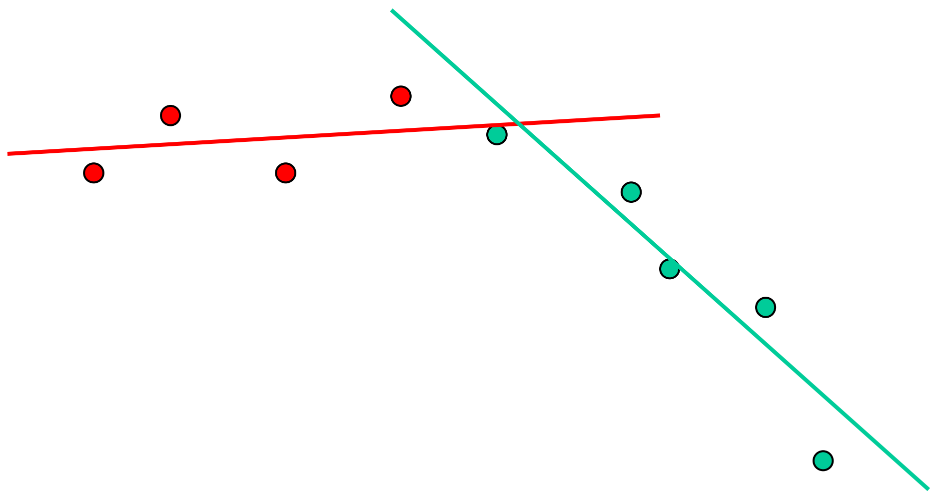
Example:



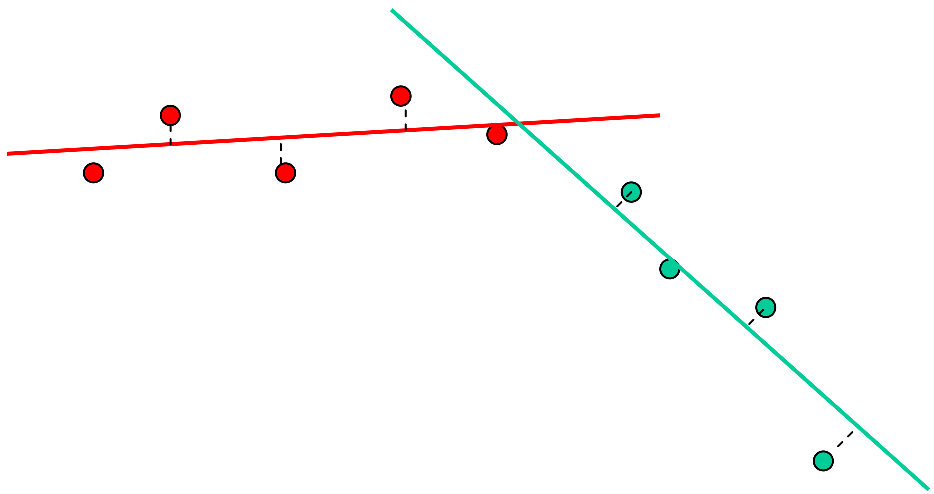
Example:



Example:



Example:



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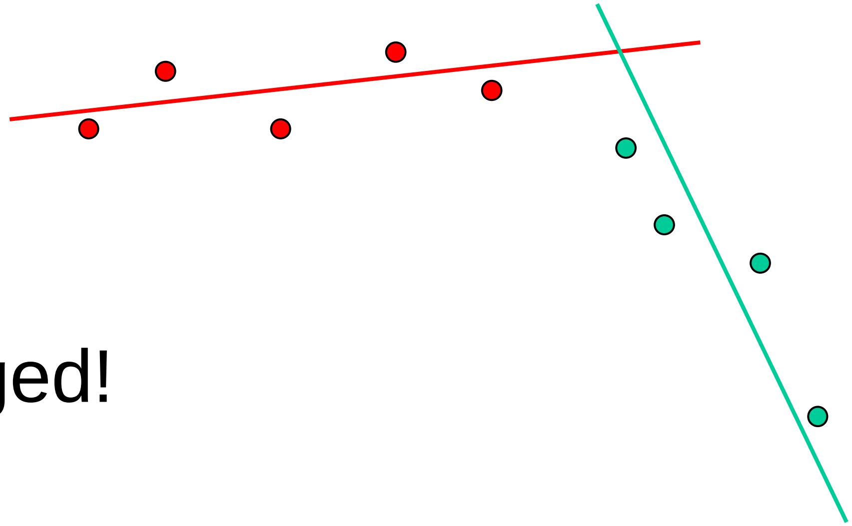


Converged!

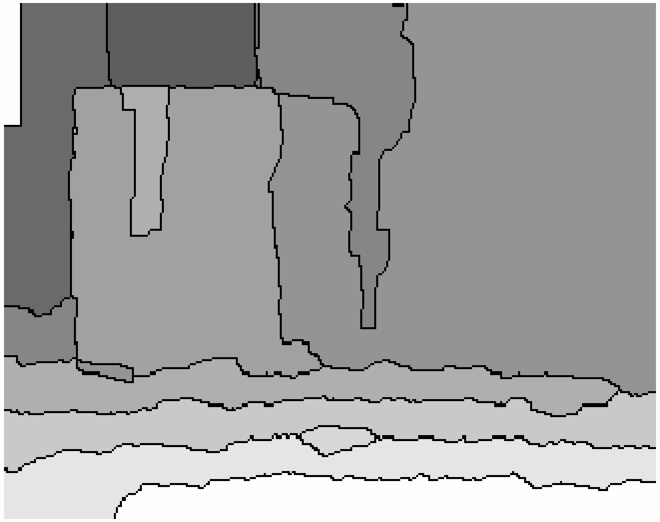
Multiway Cut for Stereo and Motion with Slanted Surfaces

Stan Birchfield and Carlo Tomasi

ICCV 1999

Motivation

an image from a stereo pair

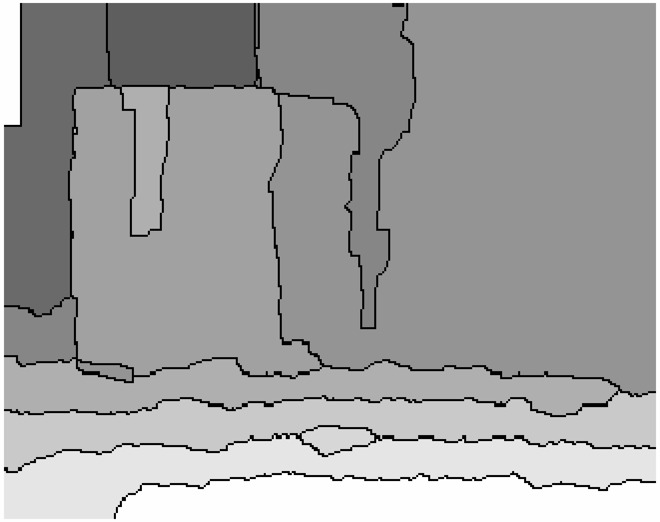


disparity map from graph cuts

- Why does it look so bad?

Solution

an image from a stereo pair



disparity map from graph cuts

- Think of this as a segmentation
  - Fit plane to each region to give more accurate results
  - Once you have these planes, reassign pixels to get better fit

Algorithm

1. Initialize a set of pixel labels
   – Run graph cuts with integer disparities
2. Fit a plane to each region (connected component)
   – They solve for an affine transformation that best aligns region in left image to corresponding region in right image
3. Assign labels (planes) to pixels
   – Use graph cuts, of course!
4. Repeat Steps 2 & 3 until convergence

- This style of algorithm should look familiar...

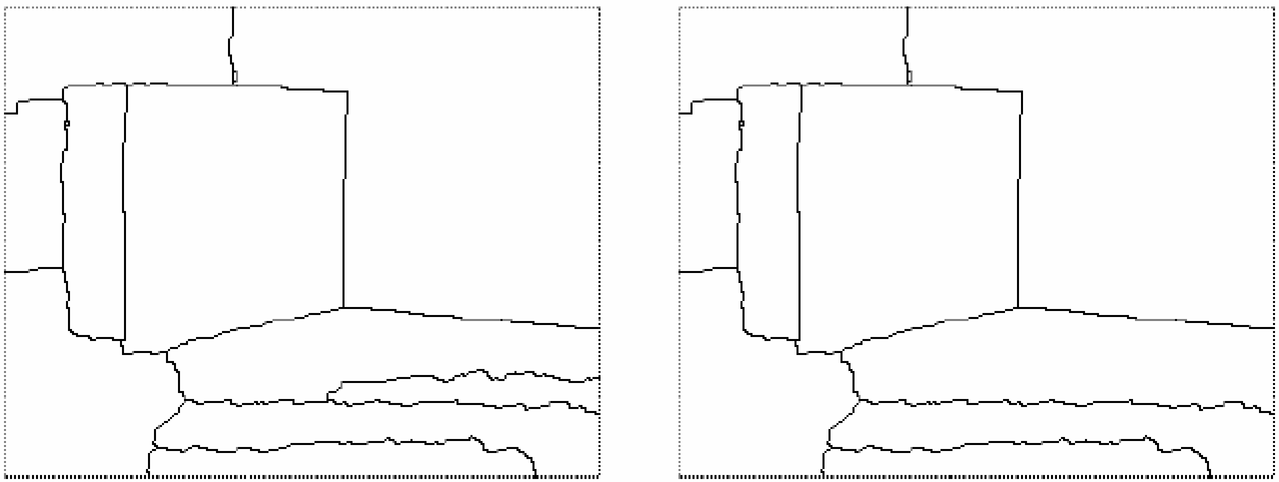
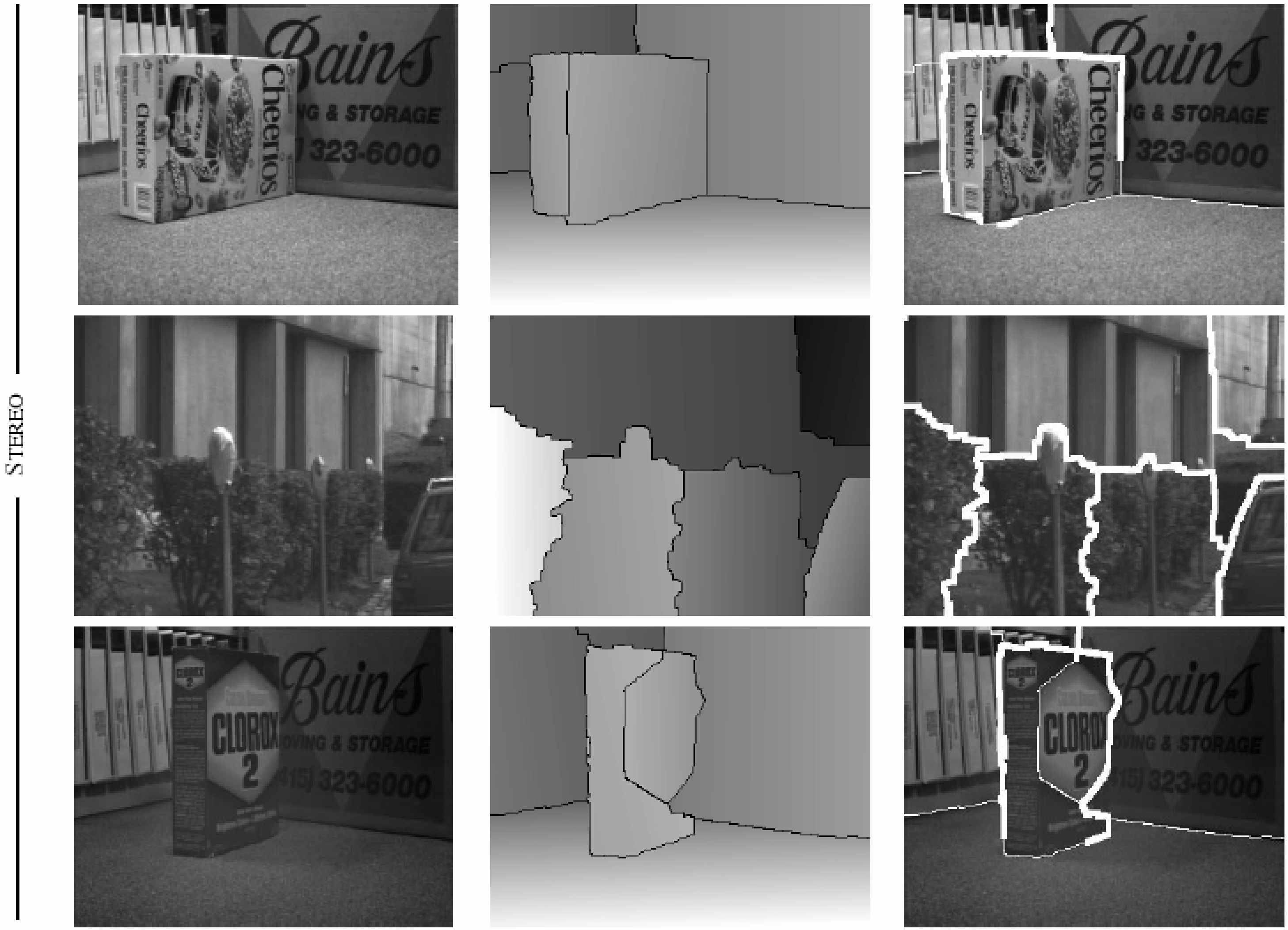


Figure 3: LEFT: Segmentation of the Cheerios image after the convergence of the multiway cut and affine-parameter fitting steps. RIGHT: Two regions on the ground plane have been merged, with more to follow.

Stereo results



Beyond simple stereo

- Graph cuts work incredibly well for stereo
  - Original successful example
- We write the energy function as

$$\sum_{p \in \mathcal{P}} D_p(f_p) + \sum_{p,q \in \mathcal{N}} T(f_p \neq f_q)$$

$$D_p(f_p) = (I(p) - I'(p + f_p))^2$$

- What assumptions are we making?
  - Frontoparallel lambertian surfaces