CS 280, Computer Vision (Prof. Jitendra Malik) Apr 19, 1999
Lecture #23 (Stereo Correspondence and Grouping / Segmentation) **DRAFT** Notes by Zhanfeng Jia

- Stereo Correspondence
- Grouping / Segmentation

1 Stereo Correspondence

Corresponding points have

- Similar values of brightness: result in high cross correlation score.
- Piecewise smoothness of disparity field.
- Uniqueness constraint: less than 1 corresponding point.
- Ordering constraint.
- Epipolar constraint: corresponding point lies on the epipolar lines.

1.1 Find disparity – simple minded

Simple consideration on epipolar constraint tells us that the matching points lie on the correponding epipolar lines. That is, P locates on the left epipolar line while the matching point P' locates on the right epipolar line. So we can search for P' along that line, using a small window of size 5 by 5 or 7 by 7. See Figure 1.

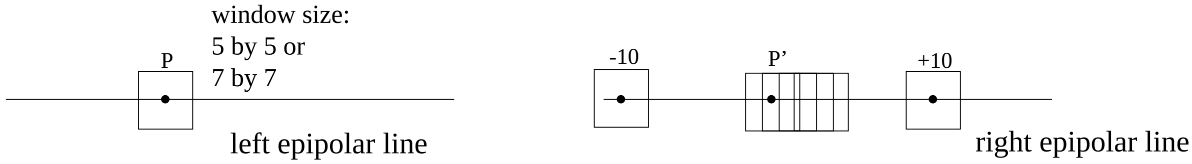

Figure 1: Disparity is function of depth. The typical range may be plus/minus 10. For each possible P', compute match-score. Define corresponding point to be one with maximal match-score. (Implement as part of homework)

The size of the matching window need to be chosen properly. Basicly, it is obvious that large window is less sensitive to noise but introduces more problems at depth boudaries. See Figure 2.

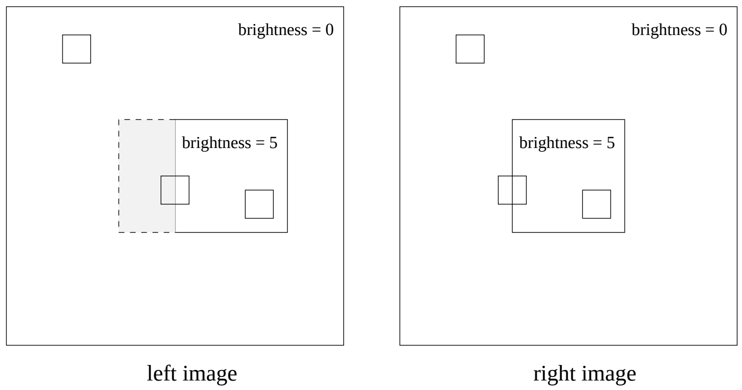

Figure 2: Size of window. The shade area exposes in the left image, but is covered in the right image. So the windows on the boundary of objects don't match well. The larger the size of window is, the less it matches.

Figure 3 shows a good way to choose window near a boundary. It avoids the problem over the bounary but depends on the decision of boundaries in advance, which is another hard-to-solve problem.

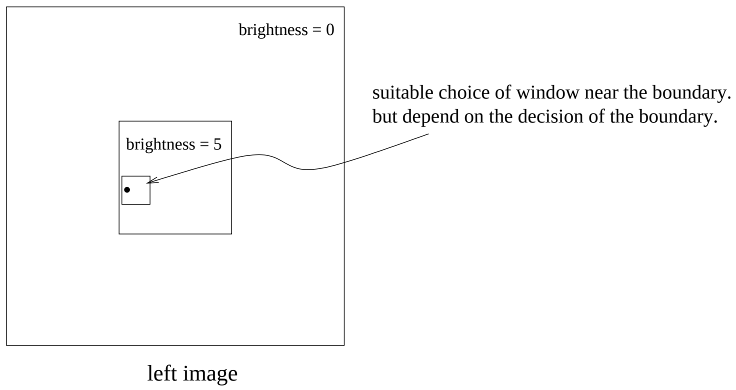

Figure 3: A suitable window choice near the boundary.

Note the fact that when P' matches P, P should match P' at the same time. So the following methods make the calculation more acurate:

1. Use the average of the two calculated disparity.
2. If the values are too different, claim no match.

1.2 Find disparity – using minimal cost path

Another property we may use in finding the matching points is continuity, that is, the 'piecewise smoothness' property listed at the very beginning. With these constraints, we introduce minimal cost path method. Refer to Figure 4.

In Figure 4, we focus on the corresponding epipolar lines from left and right images. The 'scan line' curves show the brightness value on the epipolar lines. Cost values are calculated for each pair of pixels, using cost function as following:

$$cost(m,n) = cost\ of\ matching\ pixels\ m\ and\ n$$

where m is from left epipolar line and n is from right epipolar line.

If the images contain 255 pixels each row, we get a 255*255 matrix in the end, each of the element having a corresponding cost value.

We obviously expect small cost value at matching points. Considering of continuity of disparity, the job tures out to be finding a path with as small cost values as possible frim the left-up corner of the matrix to the right-down corner. This path is called **minimal cost path**.

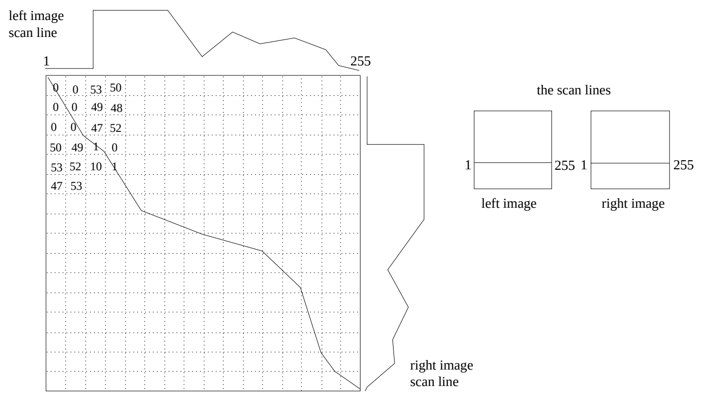

Figure 4: Cost path

How do we find minimal cost path? The answer is using dynamic programming.

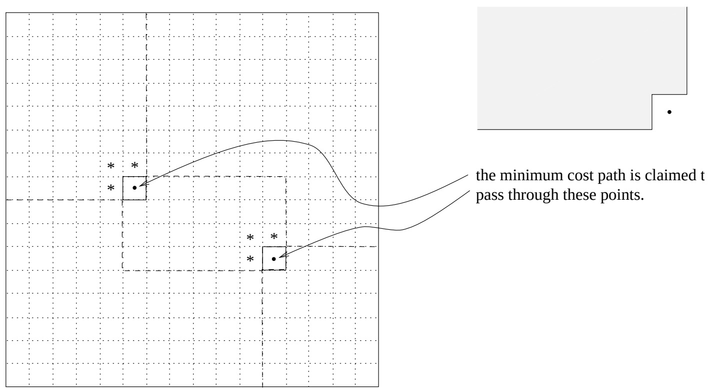

Figure 5: Dynamic programming – finding minimal cost path

Figure 5 shows the basic idea of dynamic programming. Here another property listed ahead, uniqueness constraint, is used. With the continuity constraint, it means that if the matrix element marked by dot is claimed to be part of the path, the last element on the path must be one of the three ones marked by star. Thus if we know two elements that are on the path, as showed in the Figure 5, the minimal cost path is constrained in the area marked by dash-line.

1.3 Stereo correspondence – still open

There are still some unsolved problems.

- regions without texture. Certain regions like a white wall make it impossible to find out the disparity.

- depth discontinuities, that is, regions of half-occlusion. We met this kind of problem when choosing the size of matching window. See Figure 2, 3.

Also, current continuity constraint is only one-dimensional case. Ohta and Kanade extend dynamic programming and use inter-scanline constraint. Figure 6 shows the idea.

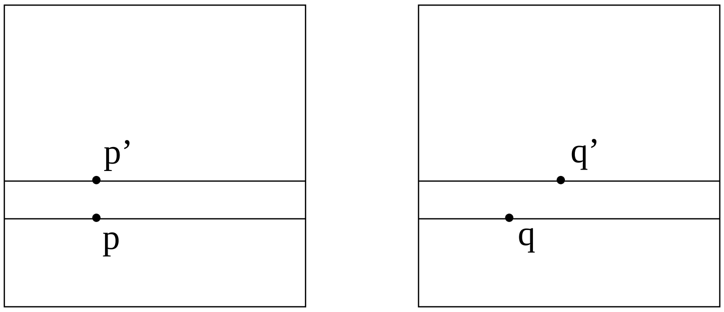

Figure 6: Extended DP by Ohta and Kanade, using the information that if p and p' are close, q and q' should also be close.

2 Grouping / Segmentation

Boundaries of image regions defined by a number of attributes.

- Brightness and color
- Texture
- Motion
- Stereoscopic depth
- Familiar configuration

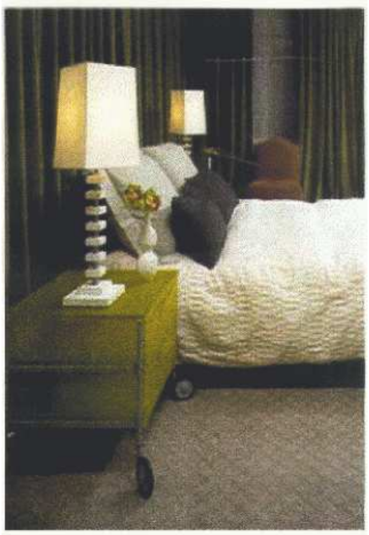

Figure 7: Example picture – bedroom

Factors that lead to grouping:

- Similarity of brightness, color, texture, disparity, motion, ...
- Proximity
- Good continuation of boundary contour
- Closure
- Symmetry and parallelism
- Familiar configuration