Chapter 11 Depth

two camera displaced from each other
range image; depth at each pixel

11.1 Stereo Imaging

* image plane; coplanar with disparity and base line apart

* epipolar plane
  epipolar line
* conjugate pair; two points in different images
  that are the projections of the same point in the scene
* disparity; distance b.t. points of a conjugate pair when the two images are superimposed

* coplanar image

$$\frac{x}{z} = \frac{x_l'}{f}$$
$$\frac{x-b}{z} = \frac{x_r'}{f}$$

$$\Rightarrow \quad z = \frac{bf}{(x_l' - x_r')}$$

Knowing the disparity => depth at the point P (x, y, z)

- wide angle stereopsis; large baseline b => increase resolution
  matching difficult

11.1.1 Cameras in arbitrary position and orientation

two cameras ; in general position and orientation
epipolar line; not parallel to image row

* two cameras; optical axes intersects at a point in space

disparity $d = x_l' - x_r'$; +
0
−

* active vision system

11.2 Stereo matching

finding the conjugate pairs
correspondence problems
for each point in the left image, find the corresponding point in the right image

points to be matched; distinctly different from its surrounding pixels
using both edge and region features
depth ; for only these feature points
for other point ; interpolated
search area; epipolar line and its neighborhood

11.2.1 Edge matching

for binocular stereo

- Filter each image with Gaussian filter
- edge position within the row
- match edges at course resolutions ; by orientation and strength
horizontal edges; cannot matched
- refine the disparity estimates by matching at fine scales; subpixel resolution

active control of camera angle; reduce false matching

11.2.2 Region correlation

edge matching; occluding edges: depth is not well defined
strong edges

* Detection of interesting points in regions
not good candidate; points in uniform region
interest operator; finds high variance, isolated area

Directional variances;

$$I_1 = \sum_{(x,y)\in S}[f(x,y)-f(x,y+1)]^2$$
$$I_2 = \sum_{(x,y)\in S}[f(x,y)-f(x+1,y)]^2$$
$$I_3 = \sum_{(x,y)\in S}[f(x,y)-f(x+1,y+1)]^2$$
$$I_4 = \sum_{(x,y)\in S}[f(x,y)-f(x+1,y-1)]^2$$

S; 5X5, 11X11 window

Interest value at central pixel (x_c, y_c)

$$I(x_c, y_c) = \min(I_1, I_2, I_3, I_4)$$

in order to reject edge points

Good interesting point; local maxima > Th

* Matching

one window; around a feature in left image

similar window; every potential matching feature in the right image

calculate correlation;

(1) based on intensity

$$r(d_x, d_y) = \frac{\sum_{(x,y)\in S}[f_1(x,y) - \overline{f_1}][f_2(x+d_x, y+d_y) - \overline{f_2}]}{\{\sum_{(x,y)\in S}[f_1(x,y) - \overline{f_1}]^2 \sum_{(x,y)\in S}[f_2(x+d_x, y+d_y) - \overline{f_2}]^2\}^{1/2}}$$

$\overline{f_1}$, $\overline{f_2}$; average intensities in the two regions

(2) thresholded signed gradient magnitude at each pixel

gradient magnitude at each pixel; using two thresholds

$$\begin{cases} -1 \\ 0 \\ 1 \end{cases}$$

no normalization

- depths of the scene points corresponding nearby feature points are to be close to one another
- difficulties; selection of interesting points

high variance: at edge, or discontinuous surface

but smoothness constraint not hold

using structured light

11.3 Shape from X

extracting shape information from intensity image

estimate local surface orientation

- Photometric stereo

camera, object; stationary

3 images of the same scene using light sources from 3 different direction

local surface orientation; using surface reflectance properties

no corresponding problem

but controlled illumination

- Shape from texture

texture properties; density, size, orientation

texture gradient; mag. and direction of the maximum change in the texture element

(circle appearing ellipses)

structuring light with regular grid; vanishing points

problems; locating and quantifing texture primitives and their properties

- Shape from focus

out of focus; blur

- Shape from motion

11.4 Range imaging

rang imaging system, range image, depth map

triangulation; structured lighting
radar ; acoustic or laser range finder

11.4.1 Structured lighting

(1) light beam and camera

$$[x\ y\ z] = \frac{b}{f\cot\Theta - x'}[x'\ y'\ f']$$

sequential nature
slow

(2) using plane of light / two dimension light pattern

light pattern on object; discontinuity, orientation and curvature change
panned light source or moving object
multiple light ; encoded pattern avoiding ambiguity

11.4.2 Imaging radar

pulsed light; phase shift
modulated beam

11.5 Active vision

biological system
actively control; parameter, characteristic of the system