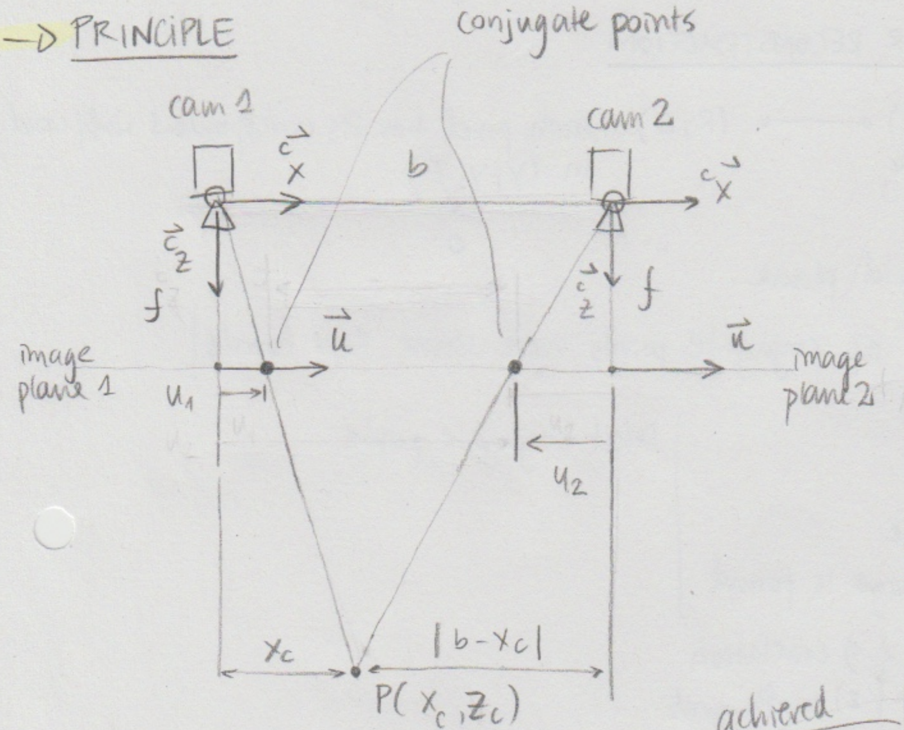
STEREO VISION

→ surfaces can be reconstructed; with 1-camera calibration we are restricted to measurement plane

- 2 methods in HALCON
  - binocular: 2 cameras, 1 view → 3D points / surface reconstructed
  - multi-view: >2 cameras, several views → — " —

→ PRINCIPLE



$\frac{f}{u} = \frac{z}{x} \longrightarrow u = f \cdot \frac{x}{z}$

$\boxed{u_1 = f \cdot \frac{x_c}{z_c}}$ image plane coordinates as seen by cam 1

$\boxed{u_2 = f \cdot \frac{x_c - b}{z_c}}$ as seen by cam 2

$\boxed{d = u_2 - u_1 = -\frac{f \cdot b}{z_c}}$ DISPARITY: difference between locations of conjugate points.

⇩

Given
① cam params (internal + rel. pose)
② image coords of conjugate points of P

achieved through

⇨ distance z_c can be computed!

$\boxed{z_c = -\frac{f b}{d}}$

① Stereo calibration: similar process to regular 1 cam 3D calibration

② Stereo matching: conjugate points found using NCC matching / multigrid methods / multi-scanline methods

- binocular_disparity / distance (NCC) (d, z_c)
- binocular_disparity_mg / distance_mg (multigrid) (d, z_c)
- binocular_disparity_ms / distance_ms

This is the binocular case — for multi-view, this is used / extended

→ SETUP

- As described above, but cams looking with diff. angles.
- Multi-view: camera pairs
- After setup, cameras cannot be touched: cam params need to be the same & (rel) pose.

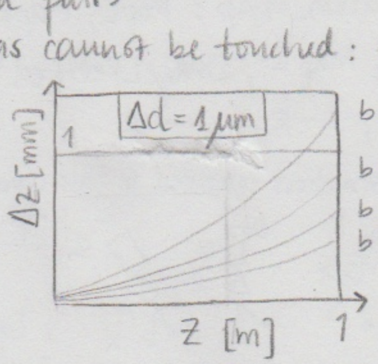
Notes:
- if b/z ⇈, stereo images might differ too much
- for planar objects higher b/z is more secure

→ RESOLUTION

$$\boxed{\Delta z = \frac{z^2}{f \cdot b} \cdot \Delta d}$$

Δz: distance resolution in $^c z$

Δd: accuracy with which disparities can be determined: example:
- calibration error ≈ 0.1 pixels
- disparity accuracy: [error, 2·error] pixels → [0.1, 0.2]
- 7.4 µm pixel size
- $\Delta d \approx 1\,\mu m$



b = 10 cm, f = 8 mm
b = 10 cm, f = 12.5 mm
b = 20 cm, f = 8 mm
b = 20 cm, f = 12.5 mm

→ for better resolution:
- increase b
- increase f

→ resolution decreases quadratically as we go further away from camera

→ TILT LENSES (see camera model & parameters) !!!

- For successful stereo reconstruction, image points must be sharp for all cameras
↓
- Tilted lenses allign focus plane of cameras due to Scheimpflug principle
↓
- Whole surface can be set in focus.

→ GENERAL INTERNAL PROCESS FOR RECONSTRUCTION

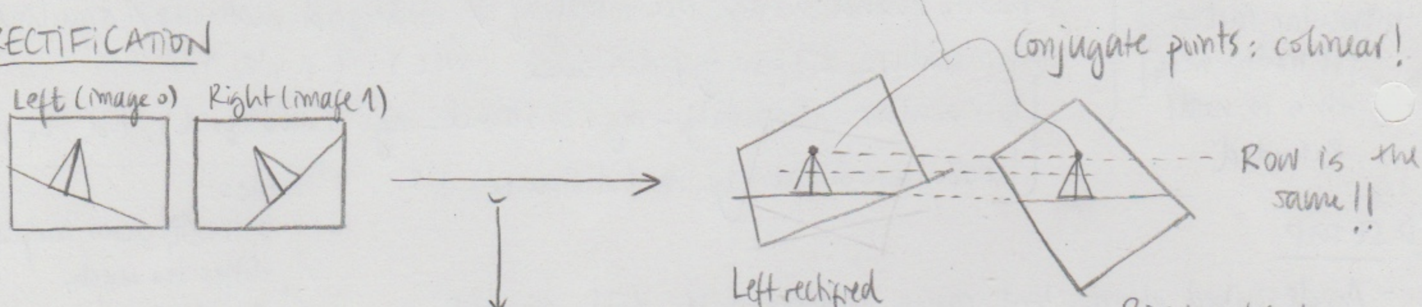
0) Camera calibration: $P(x,y,\cancel{z}) \longleftrightarrow (R,C)$: each pixel has its correspondent world coord. in $(x,y,\cancel{z})$
   $z = 0$

1) Stereo matching
   - Images are rectified to world plane
   ↓
   - After rectification all pairs of conjugate points have same Row coords!
   - for Row
     for Column
       Given R,C in an image
       its match on other image is found
   ] Detect conjugate points
       ↳ 3 methods { 1) correlation
       2) multi-grid
       3) scanline
   - With conjugate points, we basically know u_1 & u_2

$$\underbrace{\boxed{u_1, u_2}}_{\text{conjugate points}} \longrightarrow \underbrace{\boxed{d}}_{\text{disparity}} \longrightarrow \underbrace{\boxed{z}}_{\text{distance}} \text{ (as explained before)}$$

from calibration we know (x,y) for each (r,c) } → (x,y,z)

→ RECTIFICATION

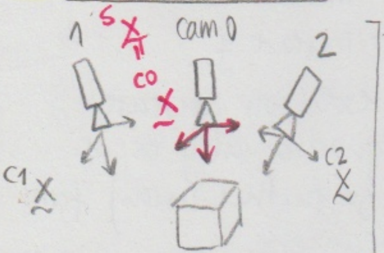


get_binocular_rectification_map : MapL, MapR
map_image (ImageL, Map L, ImageLRetifed)
map_image(-"- R, -"- R, -"- R -"-)

rectified images can be understood as images aquired by new stereo rig, obtained by rotating cams.

For perspective cams:
- Images transformed to common plane ⇒ $f_L = f_R$
- optical axes are set parallel
- same projection center

→ REFERENCE POSE : All poses of other cams & reconstruction computed in this coord sys



System ref pose set by default in coord sys of ref cam (default 0)

This can be set to world pose: adjusted (thickness) of a plate pose (eg, first: 0)