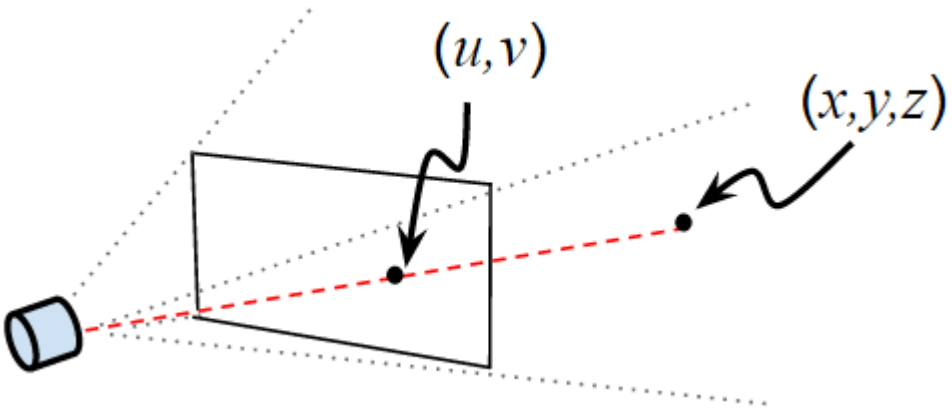
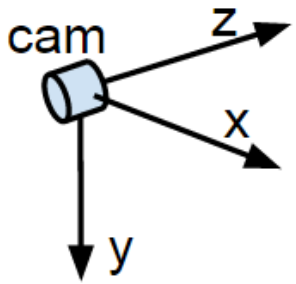
I. Plane Detection

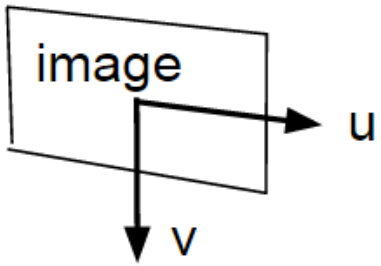
II. Ground Detection

III. RGB-Depth Image Alignment

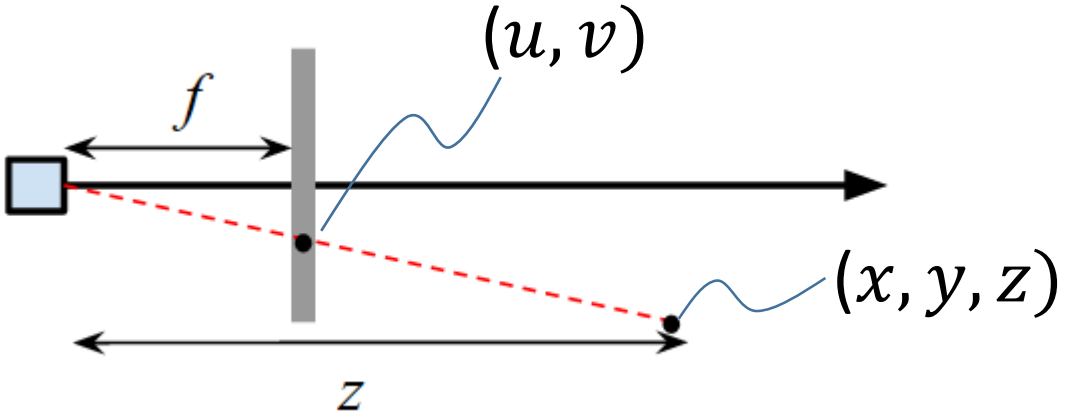
Preliminaries







Preliminaries

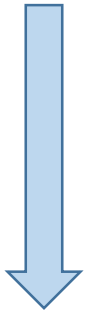


$$\frac{u}{f_u} = \frac{x}{z} \qquad \frac{v}{f_v} = \frac{y}{z}$$

Preliminaries

- Plane model in x-y-z domain

$$a_0 x + a_1 y + a_2 z + a_3 = 0$$



$$u = f_u \frac{x}{z} \qquad v = f_v \frac{y}{z}$$

- Use image (u-v) and inverse depth ($d := z^{-1}$) domain

$$a'_0 u + a'_1 v + a'_2 + a'_3 d = 0$$

I. Plane Detection
   1) RANSAC-based Estimation
   2) Clustering in Normal Space

II. Ground Detection

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Plane Detection *(1) RANSAC-based Estimation*

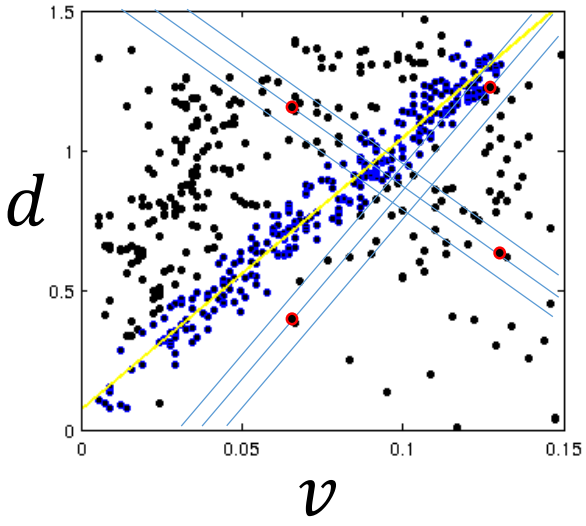
*RANSAC: RANdom SAmple Consensus

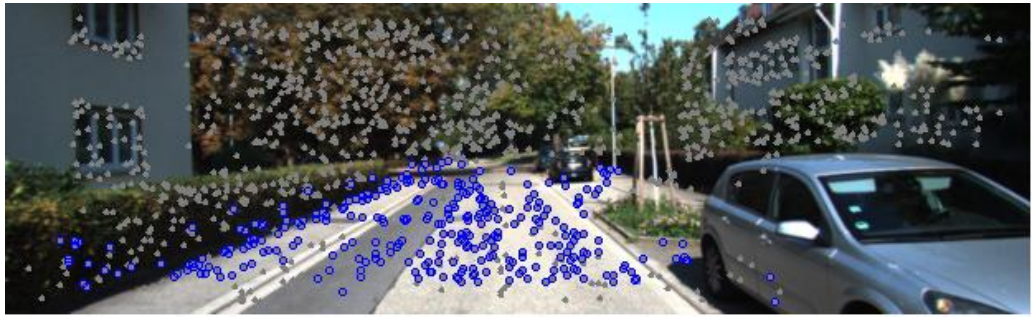
- Plane model in u-v-d domain

$$a'_0 u + a'_1 v + a'_2 + a'_3 d = 0$$

Repeat N times:
1) Generate *random* hypothesis
2) Score the hypothesis
3) Save if it is the best

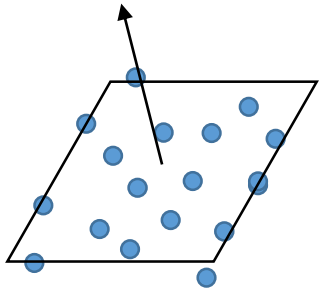
Refine the best hypothesis





Plane Detection *(2) Clustering in Normal Space*

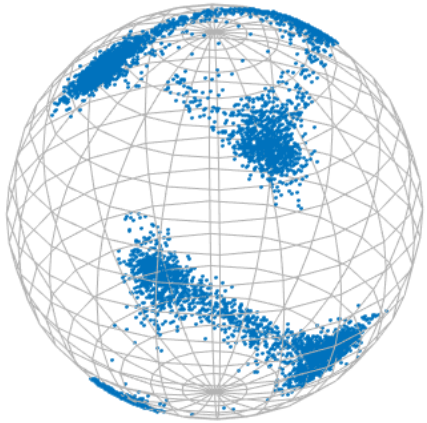
- Plane model $a'_0 u + a'_1 v + a'_2 + a'_3 d = 0$
- Local Plane Estimation (SVD)



: Normal vector can be obtained from the singular vector corresponding to the least singular value

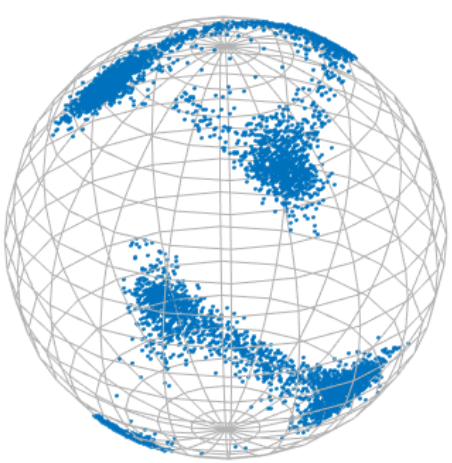
: The least singular value can be used to test "flatness"

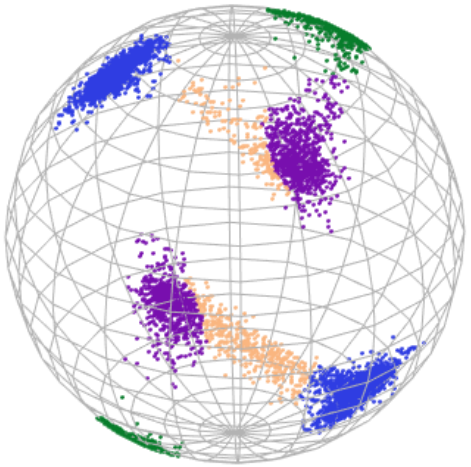
- Clustering Normal Vectors



Plane Detection *(2) Clustering in Normal Space*

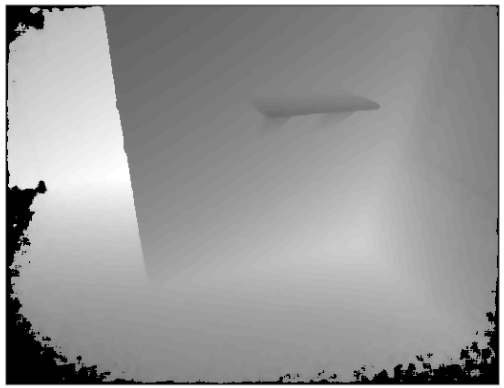
- Metric on unit sphere?
- Unsupervised Clustering
  :Design “resolution” instead of K (Number of clusters)
  For example, Mean Shift algorithm.
- Can use spatial information (u,v) as well



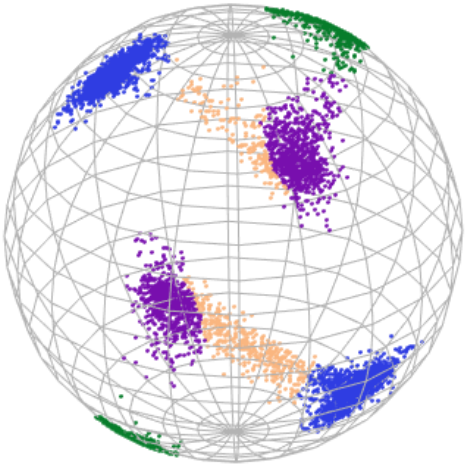


Plane Detection *(2) Clustering in Normal Space*

Input Depth Image

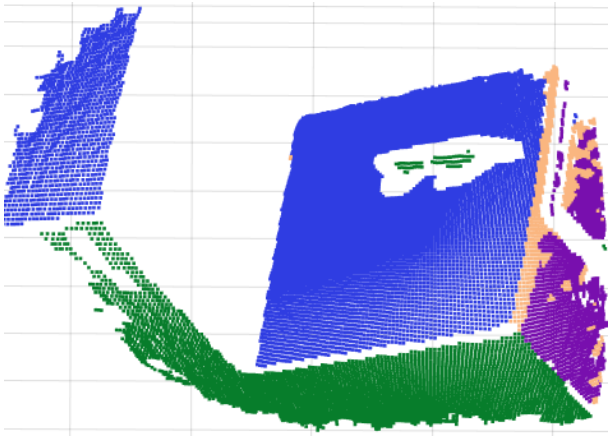


Normal Segmentation



3D Point Cloud

Segmented Planes

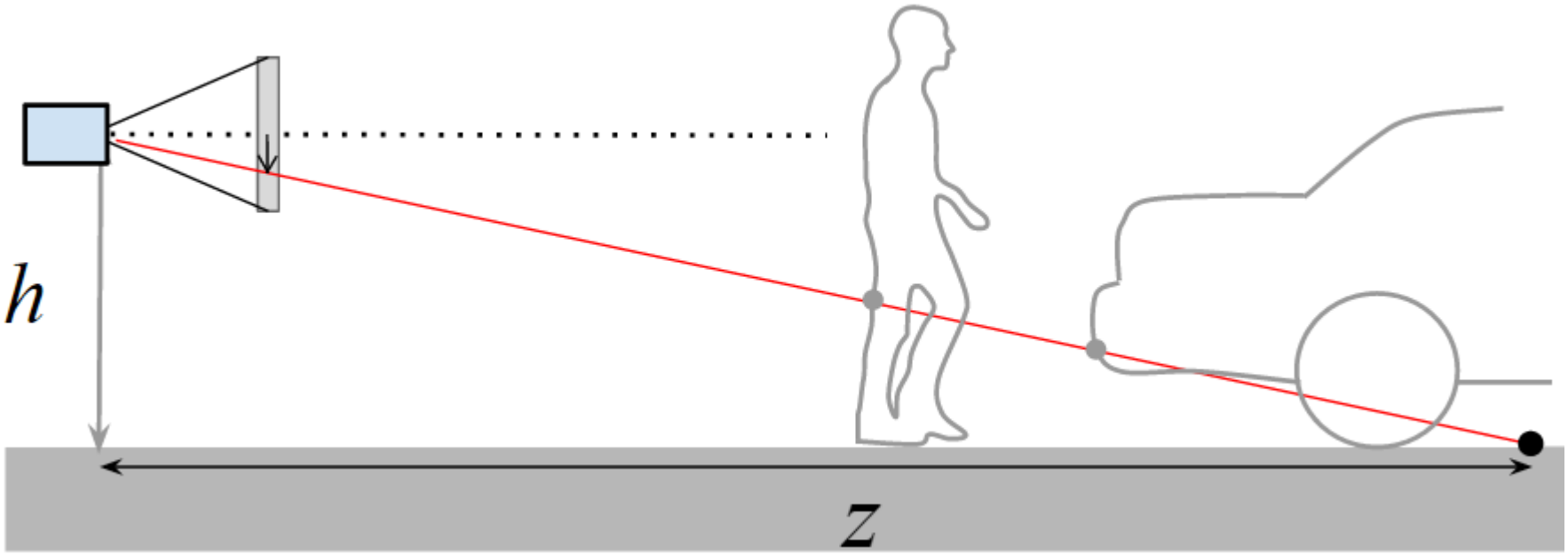


I. Plane Detection

II. Ground Detection
   1) Aligned Camera
   2) Rotated Camera

III. RGB-Depth Image Alignment

Ground Detection *(1) Aligned Camera*



Ground Plane model

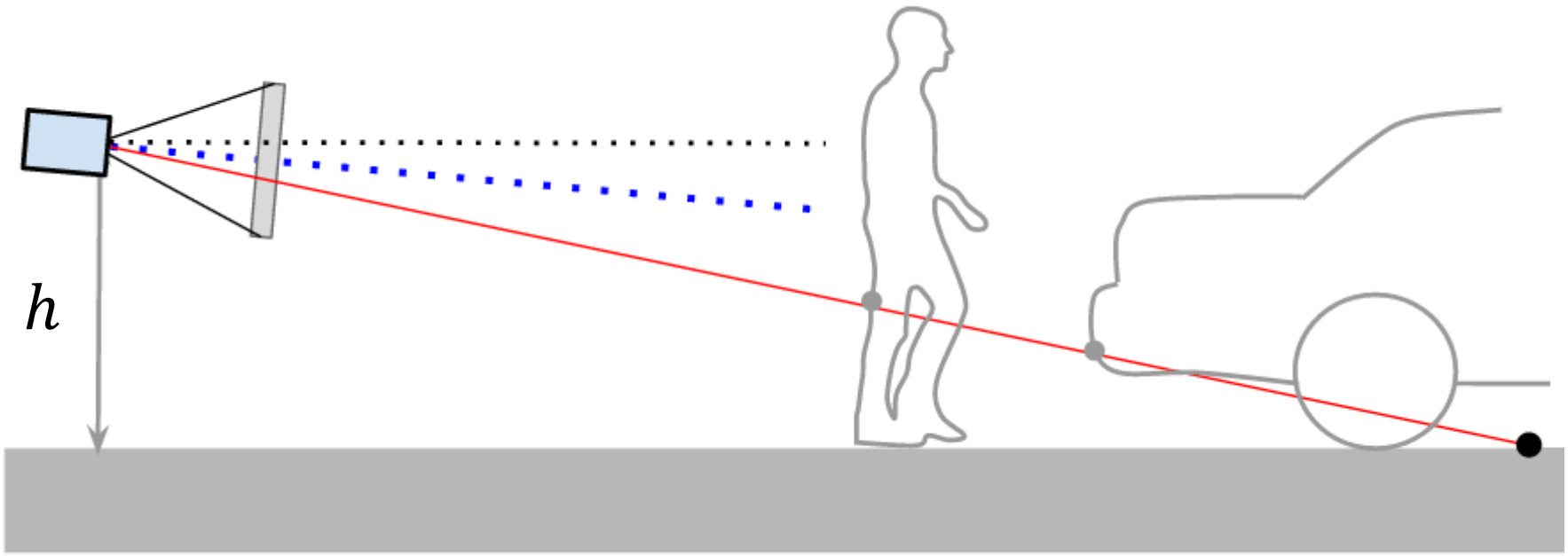
$$y = h$$

Projection

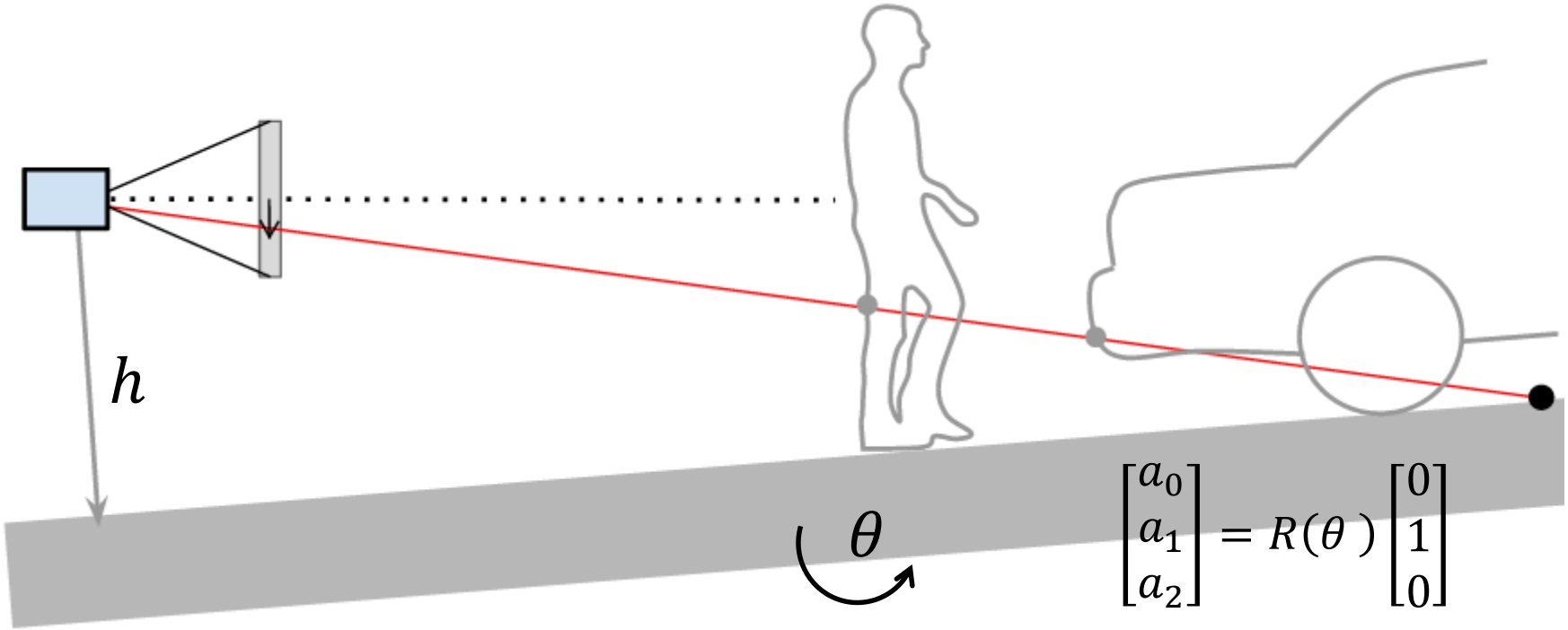
$$\frac{v}{f_v} = \frac{y}{z}$$

$$\frac{v}{f_v} = \frac{h}{z}$$

Ground Detection *(2) Rotated Camera*



Ground Detection *(2) Rotated Camera*



Ground Plane model

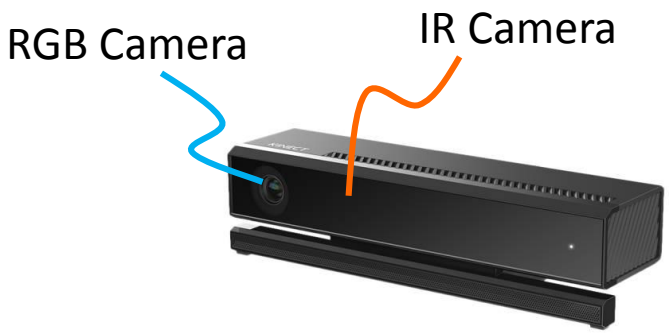
$$a_0x + a_1y + a_2z + a_3 = 0 \quad \Rightarrow \quad a'_0u + a'_1v + a'_2 + a'_3d = 0$$

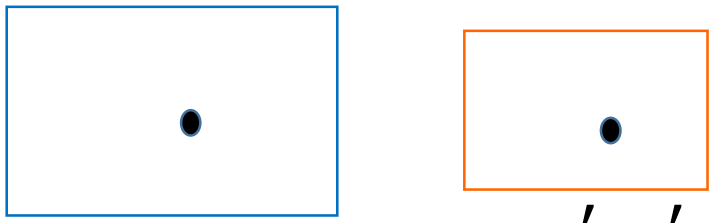
I. Plane Detection

II. Ground Detection

III. RGB-Depth Image Alignment

RGB-Depth Image Alignment

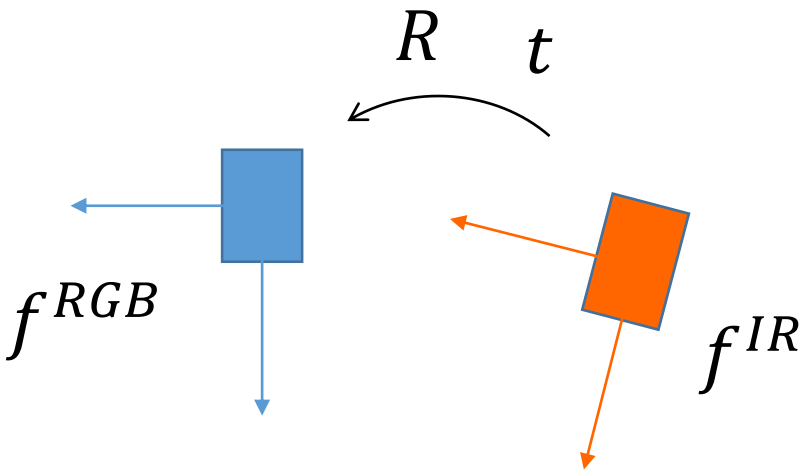




u, v

u', v'

x, y, z, r, g, b



(x, y, z)

RGB-Depth Image Alignment

Recall this: $\frac{u}{f_u} = \frac{x}{z}$

- Compute X^{IR} $x^{IR} = u'z/f^{IR}$
- Transformation $X^{RGB} = RX^{IR} + t$
- Reprojection $u = f^{RGB}\frac{x^{RGB}}{z^{RGB}}$
- Read (r,g,b) at $(u,v)^{RGB}$