Planar Structures from Line Correspondences in a Manhattan World

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Introduction

- We introduce a new algorithm for the detection and localization of planar structures and relative camera pose in a Manhattan world, using line matches from two images taken from different viewpoints.

Our method

- We use a new invariant feature (n-characteristic line) of the image of a bundle of coplanar parallel lines.
- This feature can be used to cluster visible lines into planar patches and to compute the relative camera pose.

Overview

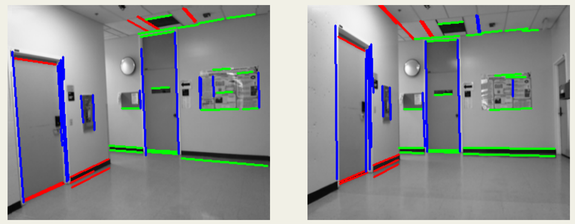
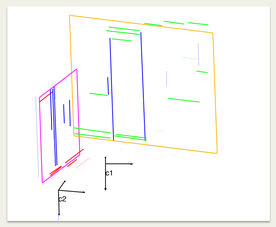


Image pair with detected lines oriented along three canonical directions in a Manhattan world

Processing steps
1. Estimate relative camera rotation using vanishing points
2. Identify line correspondences
3. Find coplanar line sets and estimate direction of camera translation by our characteristic line method

Coplanar line sets produced by our method

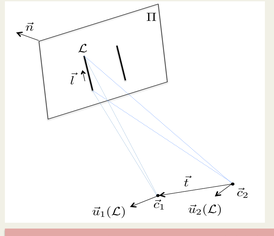


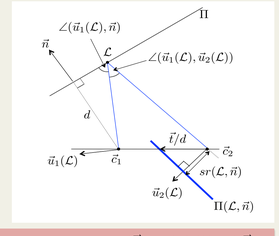
3-D reconstruction of the visible line segments, planar structures and camera center positions.

Characteristic line

- The characteristic line is defined by intersection of characteristic planes induced by coplanar parallel lines.

- **Characteristic plane $\Pi(\mathcal{L}, \vec{n})$ contains normalized baseline vector t/d**





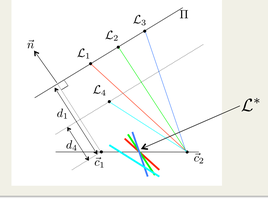
If the line $\mathcal{L}$ lies on plane $(\vec{n}, d)$, then the projection $\langle \vec{t}/d, \vec{u}_2(\mathcal{L}) \rangle$ of $\vec{t}/d$ onto $\vec{u}_2(\mathcal{L})$ is equal to $sr(\mathcal{L}, \vec{n})$

$$< \vec{t}/d, \vec{u}_2(\mathcal{L}) >= sr(\mathcal{L}, \vec{n}), \text{ where } sr(\mathcal{L}, \vec{n}) = \frac{\sin \angle(\vec{u}_1(\mathcal{L}), \vec{u}_2(\mathcal{L}))}{\sin \angle(\vec{u}_1(\mathcal{L}), \vec{n})}$$

Hence, $\vec{t}/d$ is guaranteed to lie on $\Pi(\mathcal{L}, \vec{n})$

- **Characteristic line $\mathcal{L}^*$**

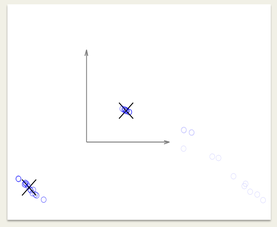
Coplanar lines ($\mathcal{L}_1$, $\mathcal{L}_2$, $\mathcal{L}_3$) induce characteristic planes that all contain the normalized baseline vector t/d_1, where d_1 is constant.
Hence, all characteristic planes intersect at $\mathcal{L}^*$, where the characteristic line $\mathcal{L}^*$ goes through t/d_1.



Characteristic line algorithm

1. For each pair of parallel lines, find the associated characteristic line
2. Find clusters of nearby characteristic lines. Each such cluster may signify the presence of a plane
3. For all characteristic lines in a cluster, label the associated parallel lines as belonging to the same plane

Identified pairs of parallel lines oriented along one canonical directions

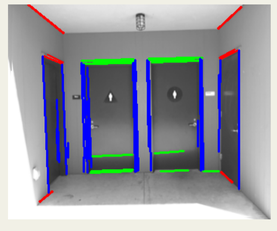


Traces of characteristic line (circles) and cluster centers found by mean-shift (crosses)

Coplanar line sets defined by the characteristic line clusters

Multiple line orientation

- The intersection of characteristic lines induced by orthogonal coplanar lines directly provides the direction of camera translation.



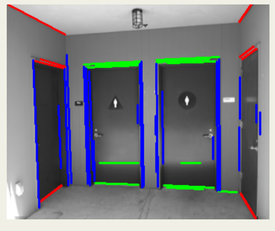
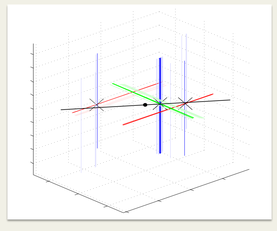


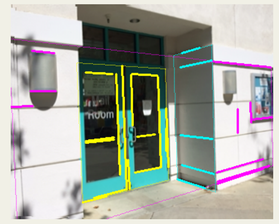
Image pair with detected lines oriented along three canonical directions (Manhattan world)

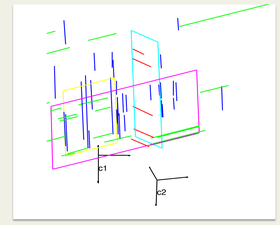


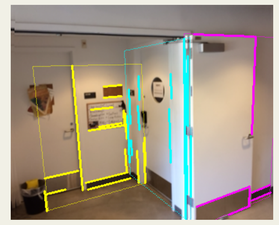
Characteristic lines for different orientations. Cluster centers identified by the mean shift (black crosses). The regressed baseline direction is represented by a black line through the origin (shown as a thick dot).

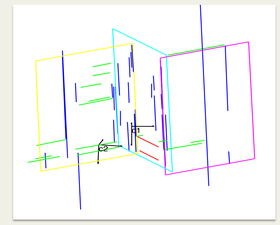
The coplanar line sets defined by the characteristic line clusters (each set drawn with a characteristic color)

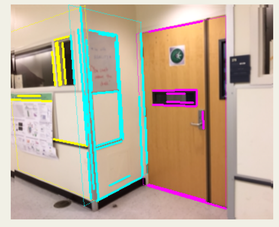
Experimental evaluation

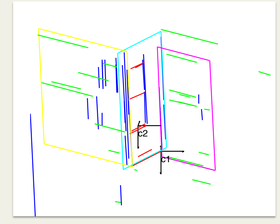


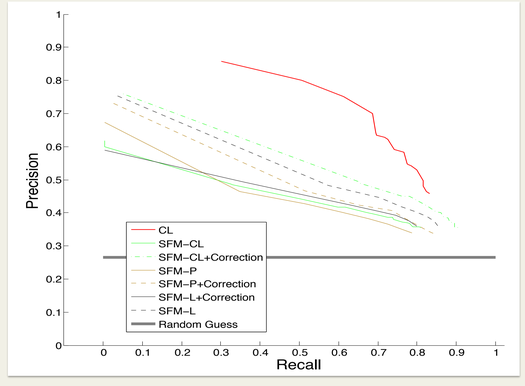












Conclusions

- We have introduced a new algorithm for the explicit detection of coplanar line sets and for the estimation of the camera motion in a Manhattan world.
- The main drawback of this approach is that it doesn't work in non–Manhattan environments, although it could conceivably be extended to support multiple plane orientations.
- Future work will extend this technique to the case of line matches over more than two images.

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