Real Projective Plane Mapping for Detection of Orthogonal Vanishing Points

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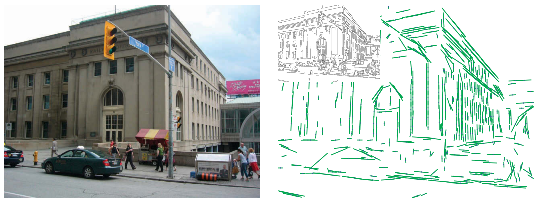


(a) Input image (b) Extracted edges

Figure 1: Detection of orthogonal vanishing points. Input image and edglets corresponding to edge points.

This paper deals with the detection of orthogonal vanishing points in the Manhattan world. We are using a modified scheme of the Cascaded Hough Transform where only one Hough space is accumulated – the space of the vanishing points. The parameterization of the VPs is based on the PClines line parameterization and it is defined as a mapping of the whole real projective plane to a finite space (the "diamond space").

Our algorithm operates directly on edgelets (Fig. 1), skipping the common step of grouping edges into straight lines or line segments. The parameterization of VPs is in all aspects linear; it involves no goniometric or other non-linear operations and thus it is suitable for implementation in embedded chips and circuitry (Fig. 3). The iterative search scheme allows for finding orthogonal triplets of VPs with high accuracy and low computational costs.

The algorithm builds upon a parameterization of lines for the Hough transform presented by Dubská *et al.* [3] and the Cascaded HT [6].

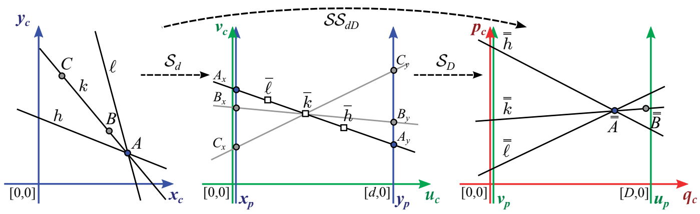


Figure 2: Cascaded PClines transformations via the straight $\mathcal{S}$ spaces (referred as $\mathcal{SS}_{dD}$ mapping). **left:** Original image space with points and lines. **middle:** The same objects in parallel coordinates **right:** Second transformation to parallel coordinates.

Mapping $\mathcal{SS}_{dD}$ (Fig. 2) is transformation of one infinite space to another infinite space. In the case of line detection, the infinite space can be replaced by two finite dual spaces [3, 6]. Dubská *et al.* [3] flip the $\mathbf{y}_p$ axis, put it in $-d$ distance and form a twisted $\mathcal{T}$ space. The CHT based on the PClines parameterization can be done by using all four combinations of the mappings. For each quadrant, a different transformation ($\mathcal{SS}, \mathcal{ST}, \mathcal{TS}$ or $\mathcal{TT}$) is used and mapped to a finite part. These four parts can be attached because images of the axes $\mathbf{x}_c, \mathbf{y}_c$ and the ideal line always lie on the borders of two segments (Fig. 4).

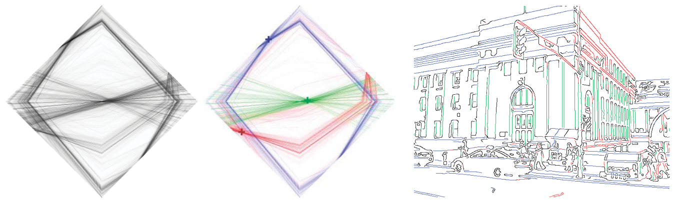
The point mappings between the original plane and the joined diamond space are:

$$[x,y,w]_o \quad [-dDw, -dx, \mathrm{sgn}(xy)x + y + \mathrm{sgn}(y)dw]_d \tag{1}$$

$$[x,y,w]_d \quad [Dy, \mathrm{sgn}(x)dx + \mathrm{sgn}(y)Dy - dDw, x]_o, \tag{2}$$

However, in the joined space, the image of a straight line is not a line anymore. The result of the mapping is a polyline whose number of segments depends on the number of quadrants the line passes. The sequence of endpoints defining the polyline corresponding to line (a,b,c) is in Eq. (3).

$$\alpha = \mathrm{sgn}(ab), \quad \beta = \mathrm{sgn}(bc), \quad \gamma = \mathrm{sgn}(ac)$$
$$\left[\frac{\alpha a}{c+\gamma a}, \frac{-\alpha c}{c+\gamma a}\right], \left[\frac{b}{c+\beta b}, 0\right], \left[0, \frac{b}{a+\alpha b}\right], \left[\frac{-\alpha a}{c+\gamma a}, \frac{\alpha c}{c+\gamma a}\right] \tag{3}$$



(a) Diamond space (right: color-coded contributions) (b) Color-coded edges

Figure 3: Accumulated "diamond space" and the affiliation of edges/contributions to different orthogonal VPs by color.

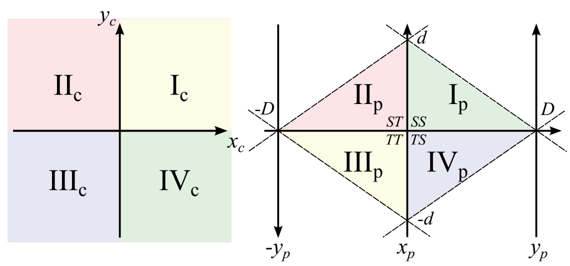


Figure 4: Quadrants of the original infinite Cartesian space. *right:* Quadrants of the PClines space (two attached spaces of parallel coordinates).

The detection accuracy is evaluated on the York Urban Database [2], consisting of 102 images, each with three orthogonal ground truth vanishing points. Our algorithm yields **98.04 %** success rate at 10° angular error tolerance with average error **1.41 %**.

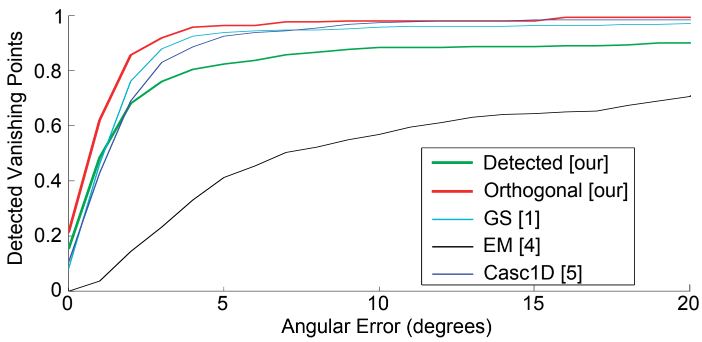


Figure 5: Cumulative histogram of the correctly detected VPs. *Horizontal axis:* angular error of the detected VPs from the ground truth. *Vertical axis:* fraction of VPs detected with the given error tolerance. **green:** Our algorithm without the orthogonalization. **red:** Our detection with the orthogonalization. **GS**, **EM** and **Casc1D** are algorithms used in [1, 4, 5].

[1] S. T. Barnard. Interpreting perspective images. *Artif. Intell.*, 21, November 1983.

[2] P. Denis, J. H. Elder, and F. J. Estrada. Efficient edge-based methods for estimating manhattan frames in urban imagery. In *ECCV 2008*.

[3] M. Dubská, A. Herout, and Havel J. PClines – line detection using parallel coordinates. In *CVPR 2011*.

[4] J. Košecká and W. Zhang. Video compass. In *ECCV 2002*.

[5] B. Li, K. Peng, X. Ying, and H. Zha. Vanishing point detection using cascaded 1D hough transform from single images. *Pattern Recognition Letters 2012*.

[6] T. Tuytelaars, M. Proesmans, L. Van Gool, and E. Mi. The cascaded Hough transform. In *Proceedings of ICIP 1998*.