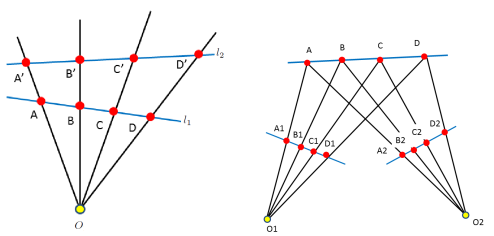
Line-Sweep: Cross-Ratio for Wide-Baseline Matching and 3D Reconstruction

Srikumar Ramalingam[1], Michel Antunes[2], Daniel Snow[1], Gim Hee Lee[1], Sudeep Pillai[3]
[1]Mitsubishi Electric Research Laboratories (MERL), Cambridge, USA. [2]Interdisciplinary Centre for Security, Reliability and Trust (SnT), University of Luxembourg, Luxembourg. [3]Massachussetts Institute of Technology (MIT), Cambridge, USA.

We propose a simple and useful idea based on cross-ratio constraint [3] for wide-baseline matching and 3D reconstruction. Most existing methods exploit feature points and planes from images. Lines have always been considered notorious for both matching and reconstruction due to the lack of good line descriptors. We propose a method to generate and match new points using virtual lines constructed using pairs of keypoints, which are obtained using standard feature point detectors. We use cross-ratio constraints to obtain an initial set of new point matches, which are subsequently used to obtain line correspondences. We develop a method that works for both calibrated and uncalibrated camera configurations.

Cross-Ratio: In Figure 1 we show a pencil of lines from center O intersecting a line l_1 at four points (A,B,C,D). The same pencil of lines also intersect another line l_2 at four other points (A',B',C',D'). The cross-ratio for the four collinear points on l_1 is defined as $\{A,B;C,D\} = \frac{|AC|\times|AD|}{|BC|\times|BD|}$. We can compute a cross-ratio $\{A',B';C',D'\}$ using the four collinear points on line l_2. By using the property of invariance of cross-ratio, we have $\{A,B;C,D\} = \{A',B';C',D'\}$. In the case of perspective projection, we have cross-ratio from four collinear points observed from different viewpoints as shown in Figure 1(b). Here we have $\{A_1,B_1;C_1,D_1\} = \{A_2,B_2;C_2,D_2\}$.



(a) (b)

Figure 1: *(a) Sets of four points have same cross-ratios on the incident pencil of lines as shown. (b) In two different perspective projections observing the same set of four collinear points, the associated cross-ratios are same.*

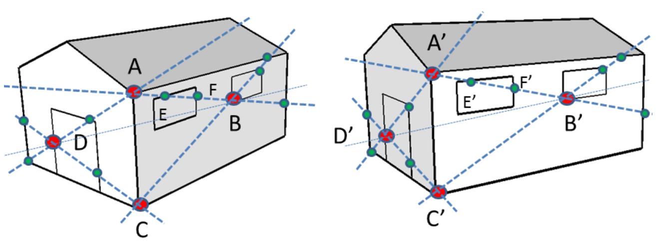


Figure 2: *We show two perspective images, taken from different viewpoints, with 4 initial keypoint matches (shown in red). By choosing pairs of keypoints, we can form virtual lines (dotted lines) where we can search for new point matches (such as the 9 new point matches shown in green).*

The Basic Idea: We refer to the lines obtained by joining pairs of keypoint matches as virtual lines. It is important to distinguish them from real lines in the image such as the ones in the rectangular windows in Figure 2. For example, the line joining A and B is referred to as a virtual line. Given a pair of keypoint matches, we consider a virtual line joining them to generate new point correspondences. The new points are first generated at regions where the virtual lines intersect the real lines. These newly generated points on the virtual lines are matched based on the cross-ratio constraint. In Figure 2, we show 4 initial point matches (marked in red) in two perspective images taken from different viewpoints. These 4 initial point matches can be obtained using feature descriptors. We consider several pairs of keypoint matches to generate newer ones. It can be observed that by using as few as 4 point matches, we are able to obtain 9 new matches (marked in green). In real images with numerous lines and keypoints, we typically have a combinatorial number of virtual lines and additional points.

The virtual lines joining pairs of keypoints allow us to match points from one image to another. This reminds us of the popular plane-sweeping technique, where we use virtual planes to compute depth maps from multiple images [1]. We will refer to our approach as *line-Sweeping*.

Experiments: We show line-matching and line-based 3D reconstruction results in Figure 4 and Figure 3 respectively. Our line-matching algorithm outperforms a recent method [2].

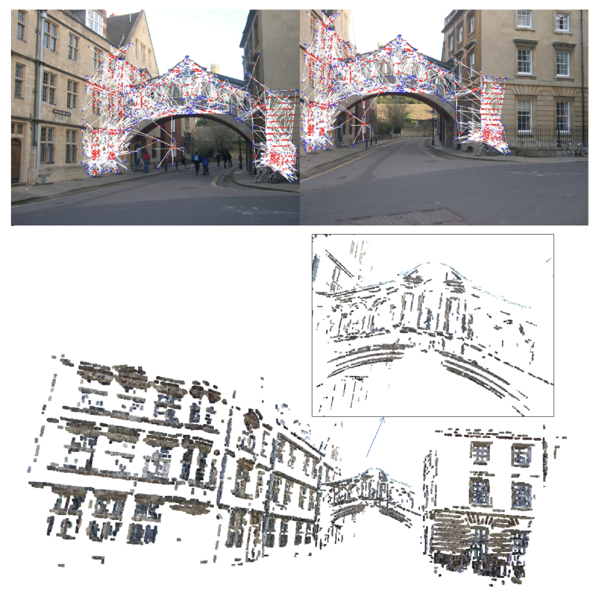


Figure 3: *Top: We consider pairs of keypoint correspondences (shown in blue) to form virtual lines (white) to identify several hundreds of additional point matches (shown in red). Bottom: We show line-based 3D reconstruction of the Bridge of Sighs in Oxford.*

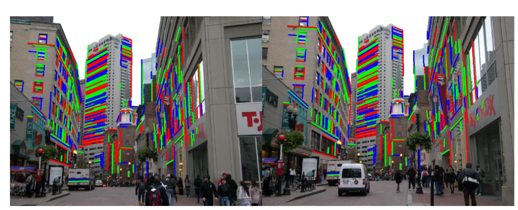


Figure 4: *Line matching results: The lines are colored red, blue and green.*

[1] R.T. Collins. A space-sweep approach to true multi-image matching. In *CVPR*, 1996.

[2] B. Fan, F. Wu, and Z. Hu. Line matching leveraged by point correspondences. In *CVPR*, 2010.

[3] J. G. Semple and G. T. Kneebone. *Algebraic Projective Geometry*. Oxford University Press, New York, 1998.

This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.