A Quantitative Evaluation of Feature Tracking Algorithms

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Model

On one rigid motion containing $t_1, ..., t_k$ trajectories, construct the measurement matrix

$$W = (t_1, t_2, ..., t_k) = \begin{pmatrix} x_1^1 & x_2^1 & ... & x_k^1 \\ y_1^1 & y_2^1 & ... & y_k^1 \\ .. & . & . & . \\ x_1^T & x_2^T & ... & x_k^T \\ y_1^T & y_2^T & ... & y_k^T \end{pmatrix} \tag{1}$$

The affine camera model factorization:

$$W = M_{2T\times 4} S_{4\times k} \tag{2}$$

Any feature trajectory t assumed to belong to this motion, beginning at frame b and ending at frame e will have a corresponding 3D structure point P obtained by least squares:

$$\begin{aligned} P &= \arg\min_P \|t - M_{be}P\|^2 \\ &= (M_{be}' M_{be})^{-1} M_{be}' t \end{aligned} \tag{3}$$

where M_{be} is the submatrix of M corresponding to the frames from b to e. Define the SSE tracking error of the trajectory t as

$$\begin{aligned} SSE(t, W) &= \min_P (t - M_{be}P)'(t - M_{be}P) \\ &= t't - t'M_{be}(M_{be}'M_{be})^{-1}M_{be}'t \end{aligned} \tag{4}$$

It can be proved that the $SSE(t, W)$ is invariant to the choice of M and S in the decomposition $W = MS$.
Define the RMSE for a trajectory t to measure the tracking error in pixels:

$$RMSE(t) = \sqrt{\frac{SSE(t)}{e - b + 1}} \tag{5}$$

Self Evaluation

- The evaluation errors on the ground truth trajectories of the Hopkins 155 dataset.

Dataset	Mean (Std)	80%	90%	Max
Checkerboard	0.20 (0.18)	0.25	0.29	0.51
Articulated	0.33 (0.32)	0.43	0.57	0.64
Traffic	0.25 (0.31)	0.37	0.42	0.61
All	0.24 (0.25)	0.37	0.43	0.64

Algorithms

Algorithm 1 Feature Pruning using Segmentation

The steps are shown below,

1. Generate trajectories by KLT
2. Segment feature trajectories (e.g. using spectral clustering).
3. For each motion label l, obtain a measurement matrix W_l from the trajectories with label l in the segmentation.
4. Compute the estimated error using eq (5) for all trajectories
5. Discard worst $p\%$ of the trajectories.

Algorithm 2 Feature Pruning using Segmentation and Robust Motion Estimation

Minimize the following energy function to find M and P robust to outliers:

$$E(M, P) = \sum_{i=1}^{n} \sum_{t=1}^{T} \ln(1 + \alpha \|M_t P_i - t_i^t\|^2) \tag{6}$$

Comparing to Algorithm 1, the only difference during the process is after getting the measure matrix W, we need to find the structure and motion matrices M and P by optimization on eq. (6).

Algorithms (Cont'd)

Algorithm 3 Feature Pruning using RankBoost

Learn to sort the trajectories using the RankBoost algorithm.

RankBoost learns a ranking $H(\mathbf{x})$ that minimizes the ranking loss,

$$L_D(f) = \sum_{(\mathbf{x}_0, \mathbf{x}_1)\in\mathcal{T}} D(x_0, x_1) I(H(\mathbf{x}_1) \le H(\mathbf{x}_0)), \tag{7}$$

where the sum is over the pairs of the training set $\mathcal{T}$, and D is the distribution function. The training set $\mathcal{T}$ contains pairs of instances $(\mathbf{x}_0, \mathbf{x}_1)$ such that $\mathbf{x}_1$ should have a larger ranking than $\mathbf{x}_0$. The function I is defined to be 1 if the prediction holds and 0 otherwise.

The features are based on the intensity and position change along the trajectory and on the trajectory geometry. The ranker has been trained using the trajectories from only four image sequences and then used to evaluate all 50 sequences. The training pairs are generated based on the ground truth trajectory errors $SSE(t)$.

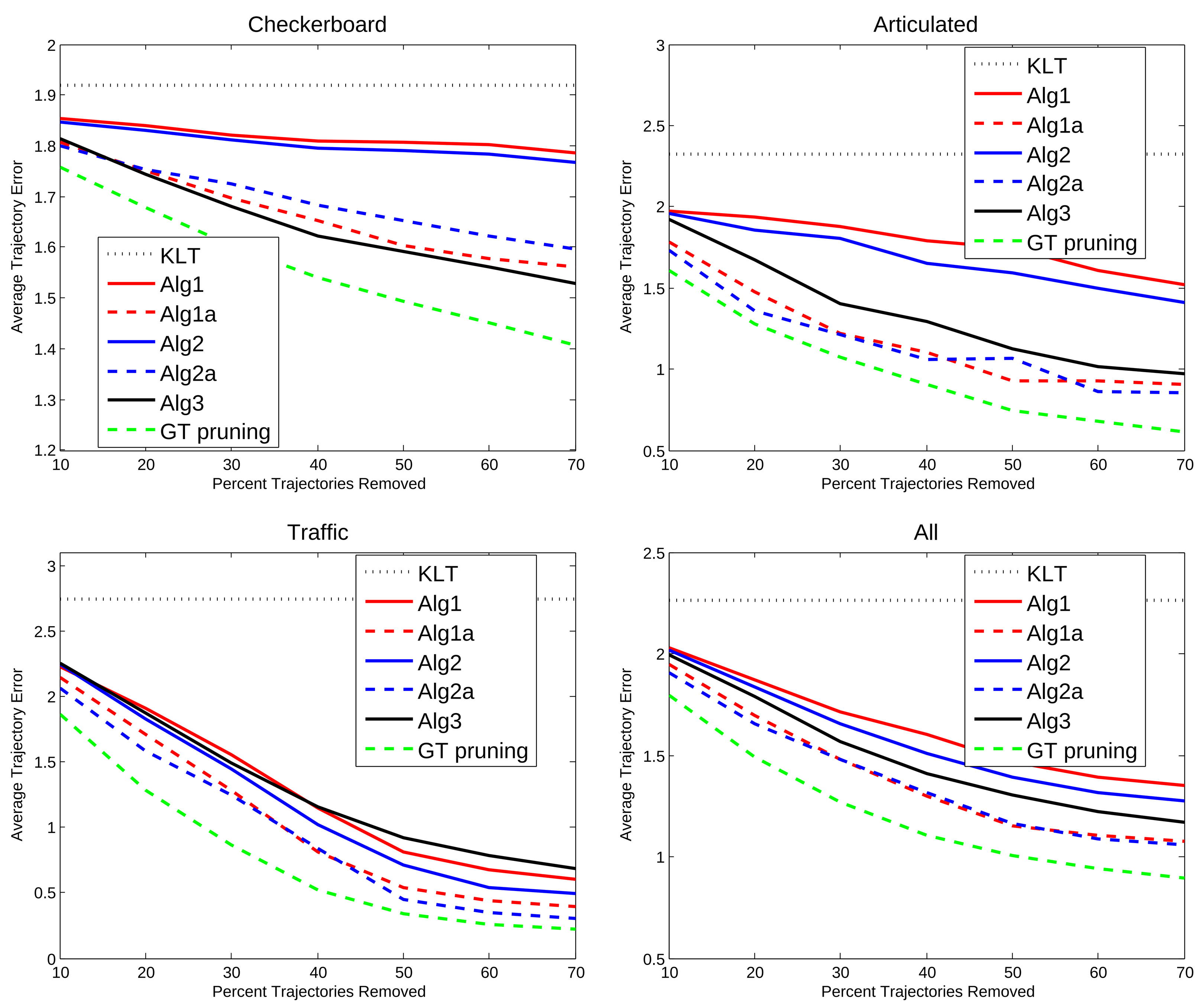
The steps are in the following,

1. Generate trajectories by KLT
2. Apply the trained ranker to sort the trajectories.
3. Discard worst $p\%$ of the trajectories.

Results

- Results of the KLT and Algorithm 3 with the same number of trajectories on frame 23 of an image sequence.

- Average tracking error for different feature tracking algorithms vs percentage of pruned trajectories. The average number of trajectories after pruning was kept at 300.



Future Works

- Handle trajectories with different lengths
- Handle incomplete trajectories