Fusing Directions and Displacements in Translation Averaging

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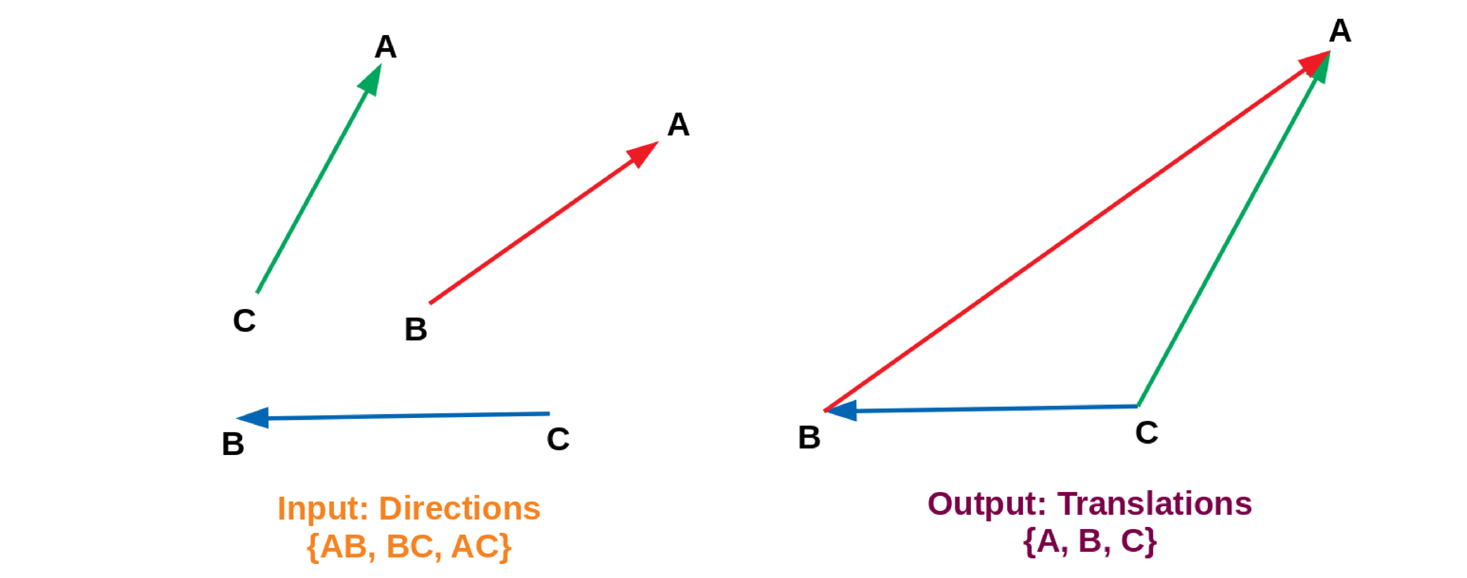
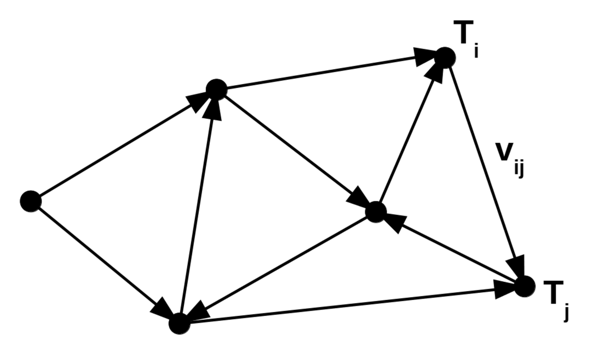
Translation Averaging



Solving for translations given directions

Problem Setup



- Graph representation: $\mathcal{G} = (\mathcal{V}, \mathcal{E})$
- Input: Directions $\mathbf{v}_{ij}$ on edges
- Output: Translations $\mathbf{T}_i$ on nodes
- Consistency equation:

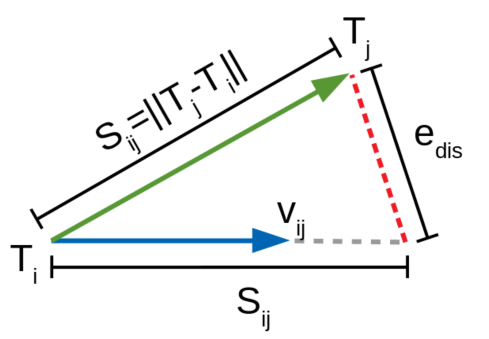
$$\frac{\mathbf{T}_j - \mathbf{T}_i}{\|\mathbf{T}_j - \mathbf{T}_i\|} = \mathbf{v}_{ij}$$

Cost Functions

Comparing Displacements

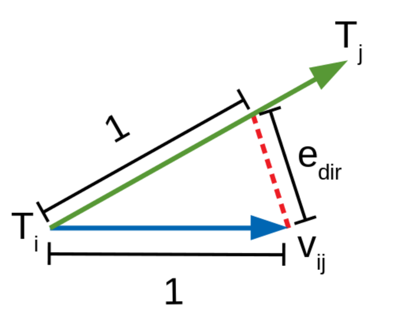
Comparing Directions

Original Costs



$$\sum_{(i,j)\in\mathcal{E}} \rho_{dis}\left(\|\mathbf{T}_j - \mathbf{T}_i - \|\mathbf{T}_j - \mathbf{T}_i\|\mathbf{v}_{ij}\|\right)$$

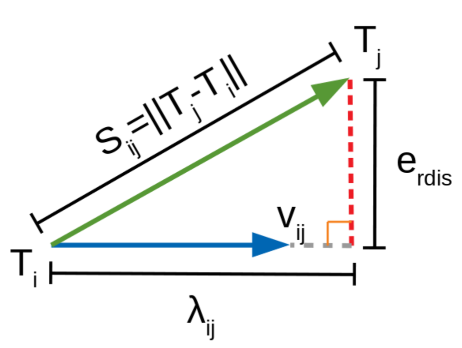
$e_{dis}(\mathbb{T})$



$$\sum_{(i,j)\in\mathcal{E}} \rho_{dir}\left(\left\|\frac{\mathbf{T}_j - \mathbf{T}_i}{\|\mathbf{T}_j - \mathbf{T}_i\|} - \mathbf{v}_{ij}\right\|\right)$$

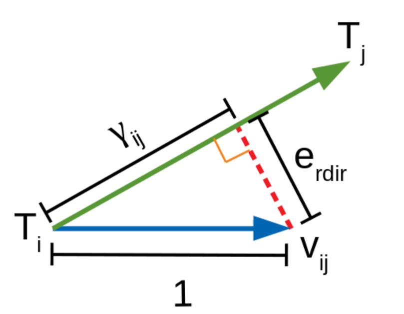
$e_{dir}(\mathbb{T})$

Relaxed Costs



$$\sum_{(i,j)\in\mathcal{E}} \rho_{rdis}\left(\|\mathbf{T}_j - \mathbf{T}_i - \lambda_{ij}\mathbf{v}_{ij}\|\right)$$

$e_{rdis}(\mathbb{T}, \Lambda)$



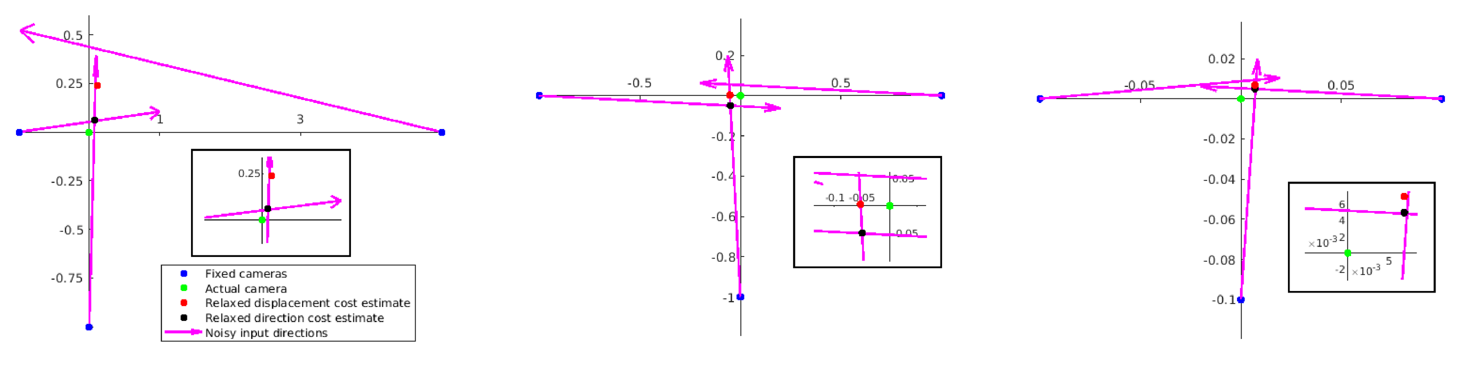
$$\sum_{(i,j)\in\mathcal{E}} \rho_{rdir}\left(\|(\mathbf{T}_j - \mathbf{T}_i)\gamma_{ij} - \mathbf{v}_{ij}\|\right)$$

$e_{rdir}(\mathbb{T}, \Gamma)$

Constraint Set:

$$\mathcal{C} = \left\{\mathbb{T} \,\middle|\, \frac{1}{|\mathcal{E}|}\sum_{(i,j)\in\mathcal{E}} \langle \mathbf{T}_j - \mathbf{T}_i, \mathbf{v}_{ij}\rangle = 1, \sum_{i\in\mathcal{V}} \mathbf{T}_i = \mathbf{0}\right\}$$

Behaviour of the Relaxed Costs



Disparate baselines $\eta = \{3°, 4°, 5°\}$ Baselines $= \{1, 1, 5\}$ units

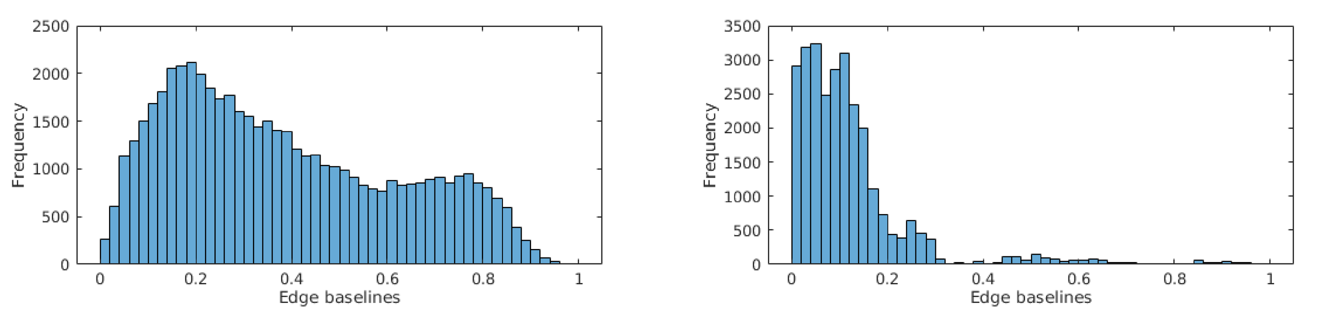
Similar baselines $\eta = \{3°, 3°, 3°\}$ Baselines $= \{1, 1, 1\}$ units

Similar baselines $\eta = \{5°, 4°, 3°\}$ Baselines $= \{0.1, 0.1, 0.1\}$ units

Behaviour of relaxed costs under varied baselines and noise η

Neither cost performs the best in all the scenarios

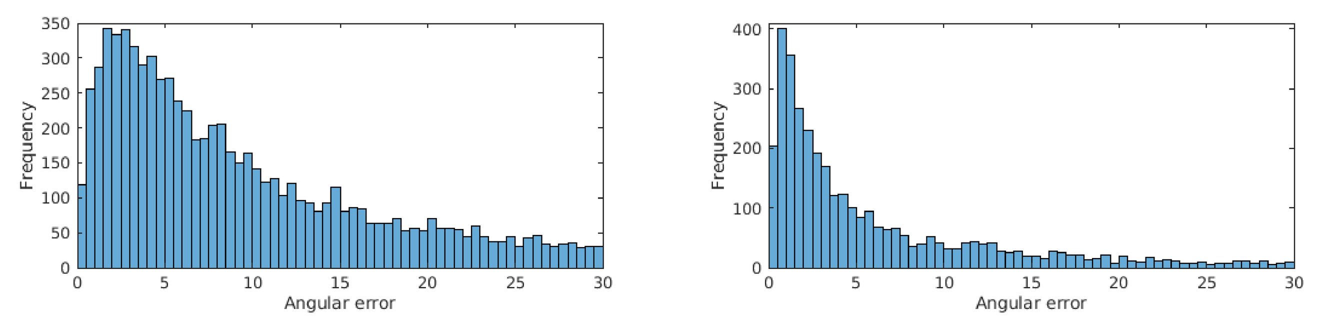
Analysis of Real Data



Montreal Notre Dame — Yorkminster

Histograms of ground truth normalized baselines

Distribution of baselines impacts performance

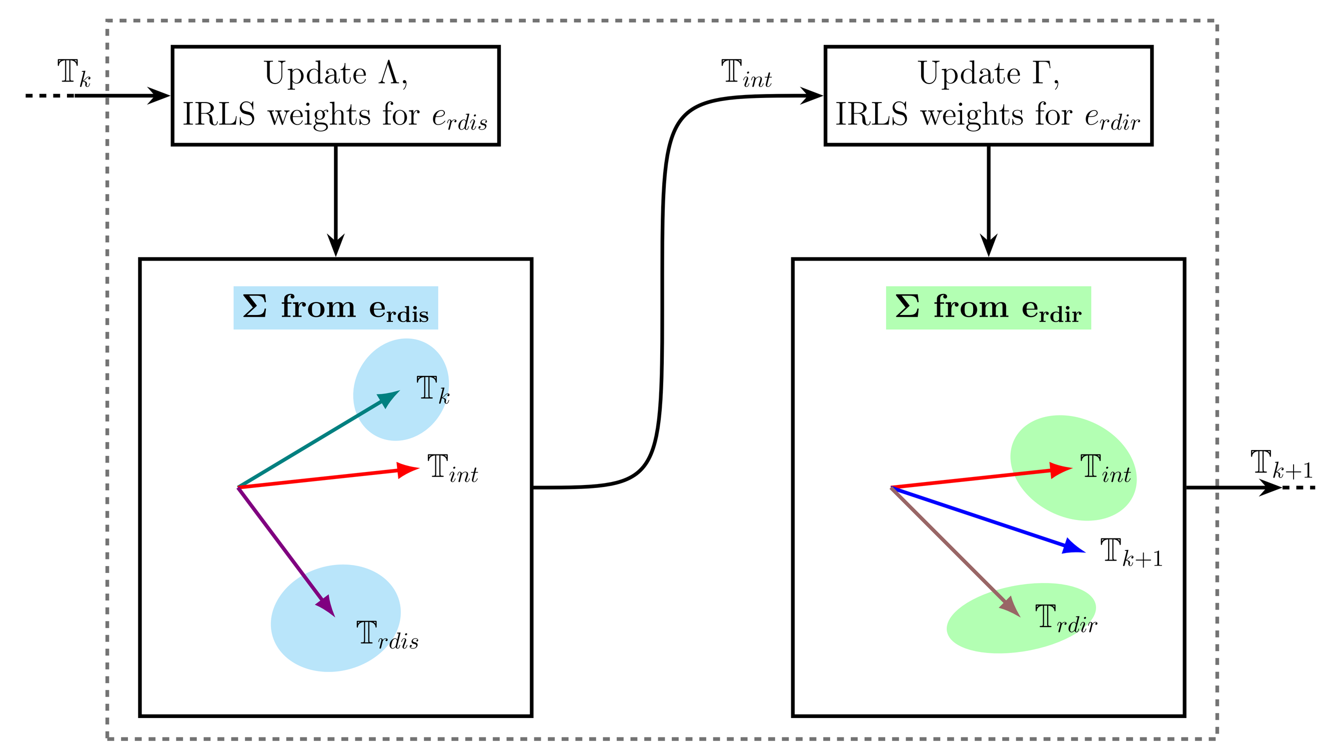


Ellis Island — Madrid Metropolis

Histograms of input direction errors (in degrees)

Distribution of noise impacts performance

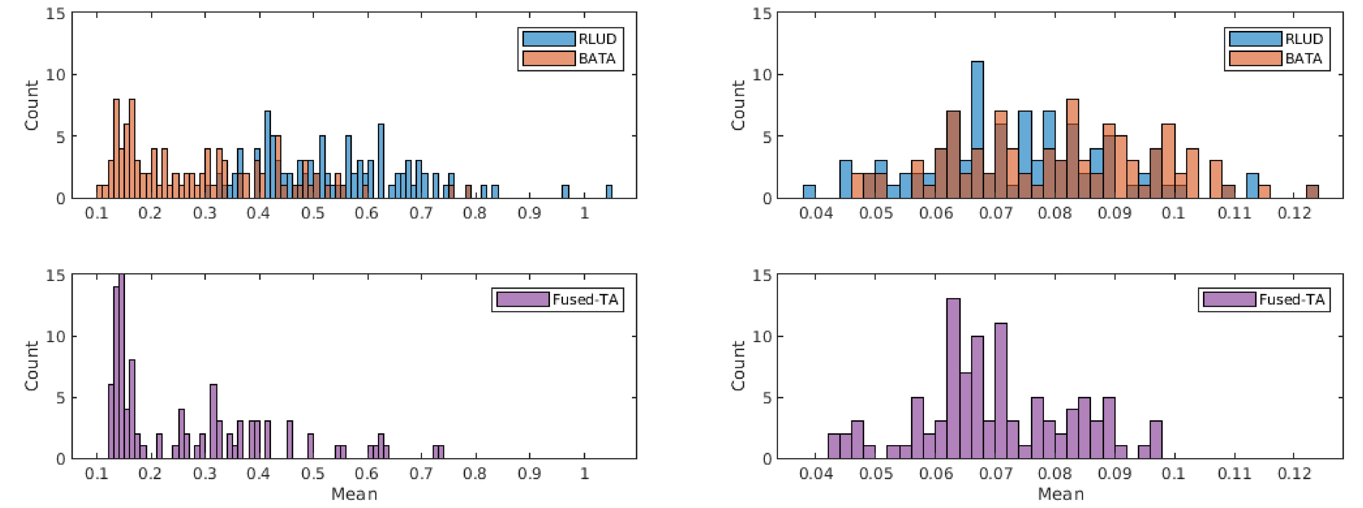
Our IRLS Method: Fused Translation Averaging



Gaussian assumption:

- Σ^{-1} = Hessian of the corresponding cost
- Bayesian update: $\mathbb{T} = \left(\Sigma_1^{-1} + \Sigma_2^{-1}\right)^{-1}\left(\Sigma_1^{-1}\mathbb{T}_1 + \Sigma_2^{-1}\mathbb{T}_2\right)$

Results



Disparate baselines with input noise $\sigma = 5$ — Similar baselines with input noise $\sigma = 5$

Histogram of mean translation errors for two synthetic datasets.

The leftward shift indicates the superior performance of our method

Dataset	$\|\mathcal{V}\|$	$\|\mathcal{E}\|$	Mean Errors					Median Errors				
			1DSfM [3]	LUD [2]	ShapeFit [1]	BATA [4]	Fused-TA (Ours)	1DSfM [3]	LUD [2]	ShapeFit [1]	BATA [4]	Fused-TA (Ours)
Alamo (ALM)	1016	16831	8e3	7.6	35.3	7.5	**7.0**	**2.4**	3.0	2.6	**2.4**	**2.4**
Ellis Island (ELS)	908	10383	107.3	45.1	39.7	42.6	**27.3**	32.3	26.0	**15.6**	25.3	17.5
Gendarmenkmart (GMM)	1026	14175	3e4	**42.3**	51.3	43.6	44.4	27.5	**25.9**	32.3	26.3	27.7
Madrid Metropolis (MDR)	627	4941	2e4	17.5	170.8	**15.3**	15.7	5.4	8.7	5.5	**4.8**	6.1
Montreal Notre Dame (MND)	599	18390	1e3	**4.0**	4.3	4.5	4.3	1.9	2.4	2.3	1.9	**1.8**
Notre Dame (ND)	1421	70771	4e4	4.0	3.7	**3.3**	**3.3**	**1.2**	1.8	1.3	**1.2**	**1.2**
NYC Library (NYC)	858	8173	3e4	**6.4**	3e3	8.2	7.6	3.1	3.0	3.6	2.5	**2.3**
Piazza del Popolo (PDP)	1038	15182	6e4	8.0	19.1	8.1	**7.6**	7.2	5.5	15.8	5.0	**4.5**
Piccadilly (PIC)	3124	46754	3e4	**6.5**	25.2	7.0	6.7	2.2	2.6	2.4	2.3	**2.1**
Roman Forum (ROF)	1575	19593	5e5	22.4	33.5	15.5	**15.3**	4.3	8.6	8.6	**4.4**	5.3
Tower of London (TOL)	824	9457	8e4	28.2	58.0	**22.9**	24.5	8.0	10.7	8.6	6.9	**6.5**
Trafalgar (TFG)	7483	115052	4e4	21.4	33.3	22.4	**21.3**	11.7	7.6	8.3	6.9	**6.2**
Union Square (USQ)	1166	13460	2e4	**14.5**	23.0	17.1	31.7	9.2	8.5	14.3	8.1	**7.9**
Vienna Cathedral (VNC)	1647	27386	7e4	14.8	172.0	14.9	**14.3**	12.8	6.5	7.1	6.5	**6.1**
Yorkminster (YKM)	1834	19177	7e4	21.1	72.6	21.6	**20.7**	22.9	12.9	15.8	13.2	**13.0**

Camera translation errors (in meters) on 1DSfM [3] datasets

Alamo — Montreal Notre Dame — Piazza del Popolo — Tower of London

Reconstructions obtained with triangulation using our Fused-TA translation estimate

Conclusion

Solving translation averaging:

- Displacement vs Direction costs
- No clear winner
- Our method: Similar to Bayes recursive filter
- Improves over individual methods

References

[1] Goldstein, T., Hand, P., Lee, C., Voroninski, V., Soatto, S.: Shapefit and shapekick for robust, scalable structure from motion. In: ECCV (2016)

[2] Ozyesil, O., Singer, A.: Robust camera location estimation by convex programming. In: CVPR (2015)

[3] Wilson, K., Snavely, N.: Robust global translations with 1dsfm. In: ECCV (2014)

[4] Zhuang, B., Cheong, L.F., Lee, G.H.: Baseline desensitizing in translation averaging. In: CVPR (2018)

Acknowledgments

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https://ee.iisc.ac.in/cvlab/research/fusedta/