Feature Trajectory Retrieval with Application to Accurate Structure and Motion Recovery

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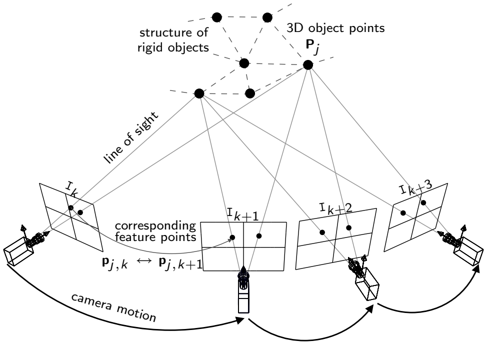
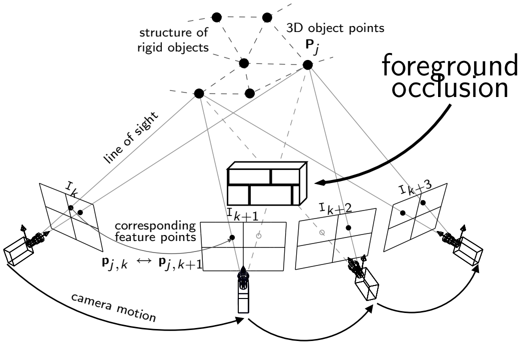
Structure and Motion Estimation



- Feature detection
- Correspondence analysis
- Outlier detection
- Bundle adjustment

Structure and Motion Estimation



- Occlusion

⇒ Trajectories lost

⇒ Error-prone object points

⇒ Drift

Reconstruction Accuracy

High-Accuracy needed for Structure and Motion Estimation

- Reprojection Errors of 1/4 pel are visible and disturbing[a]
- Need wide baseline correspondence analysis → SIFT

[a] Hillman et al., ICIP 2010

Limited Localization Accuracy

- SIFT designed for Object Recognition
- Due to more invariance, the detector looses Accuracy
- Increase localization accuracy of SIFT detector[a]

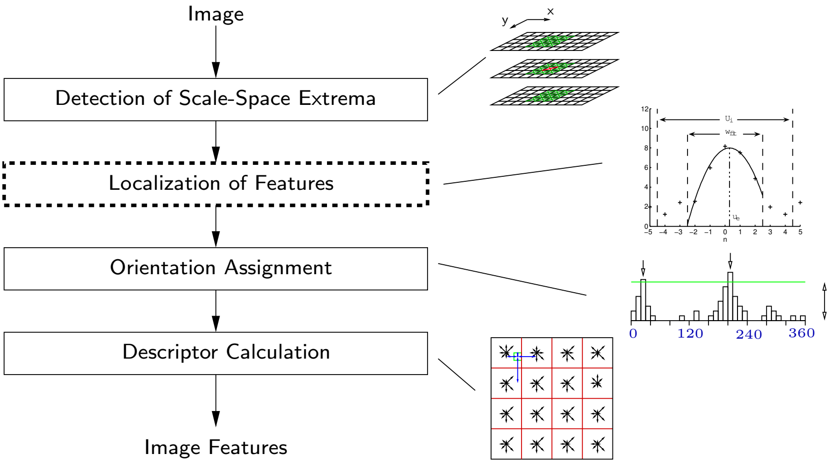
[a] Cordes et al., ISVC 2010, LNCS 6453

Objectives

- Solve occlusion problem
  - → Store discontinued trajectories
  - → Use SIFT for robust assignment of newly appearing features
- Increase localization accuracy of SIFT
  - → Use gradient signal approximation for subpel localization

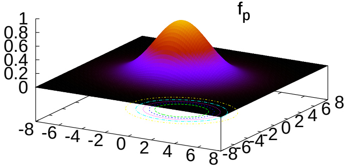
Outline

Scale Invariant Feature Transform



Bivariate Feature Localization Assuming a Gaussian Shape

$$f_{\mathbf{p}}(\mathbf{x}) = \frac{v}{\sqrt{|\Sigma|}} \cdot e^{-\frac{1}{2}((\mathbf{x}-\mathbf{x}_0)^\top \Sigma^{-1}(\mathbf{x}-\mathbf{x}_0))} \quad (1)$$



New Localization Strategy:

→ Exchange parabolic approximation of DoG by Gaussian function

- Covariance matrix $\Sigma = \begin{pmatrix} a^2 & b \\ b & c^2 \end{pmatrix} \Rightarrow$ rotated, scaled ellipse
- $\mathbf{x} = (x_0, y_0)$ subpel position

Outline

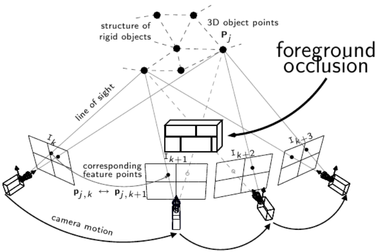
Bivariate Feature Localization Assuming a Gaussian Shape

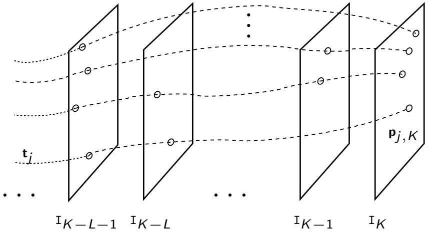
Feature Trajectory Retrieval

Experimental Results

Conclusion

Feature tracking situation





Objective: Additional constraints in bundle adjustment:

- Memory for discontinued trajectories
- use SIFT descriptor for assignment
- use RANSAC and epipolar geometry for outlier elimination

Bundle Adjustment

Bundle Adjustment Equation

$$\epsilon = \sum_{j=1}^{J} \sum_{k=1}^{K} d(\mathbf{p}_{j,k}, \mathtt{A}_k \mathbf{P}_j)^2 \rightarrow MIN \quad (2)$$

- $RMSE_\epsilon = \sqrt{\frac{\epsilon}{2JK}}$ reprojection error (RootMeanSquareError).

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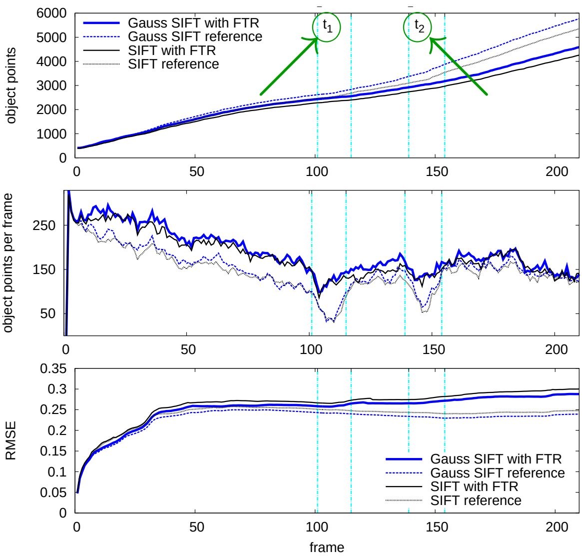
Extend Bundle Adjustment Equation

- use correspondences from non-consecutive frames
- assign detected features to already reconstructed object points
- RMSE increases for FTR because of additional constraints in the BA

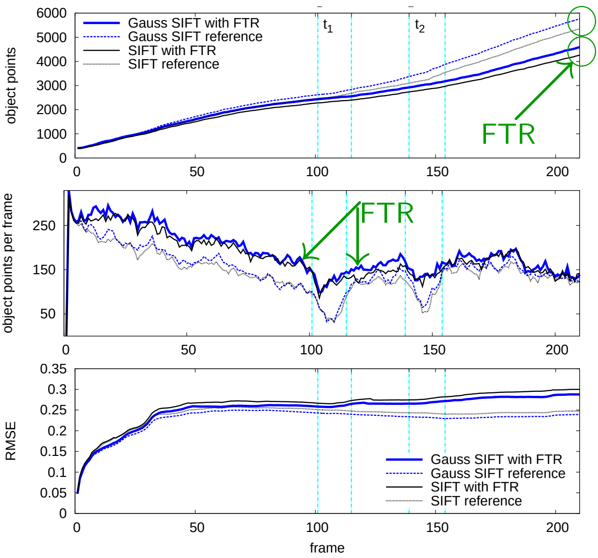
Outline



Bellevue Sequence

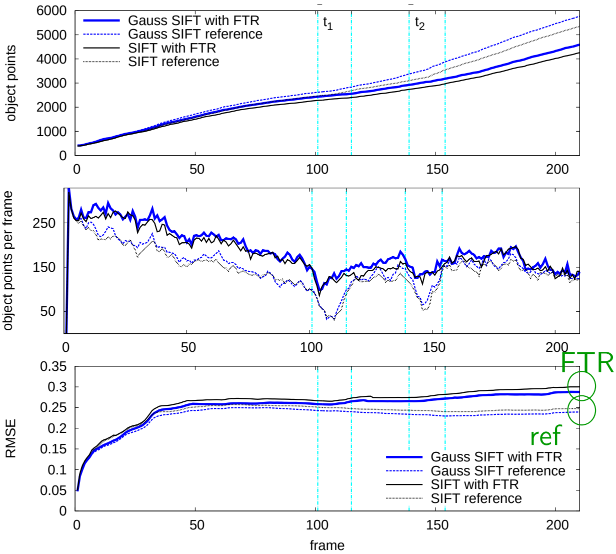
- temporary occlusions

Experimental Results



Bellevue Sequence

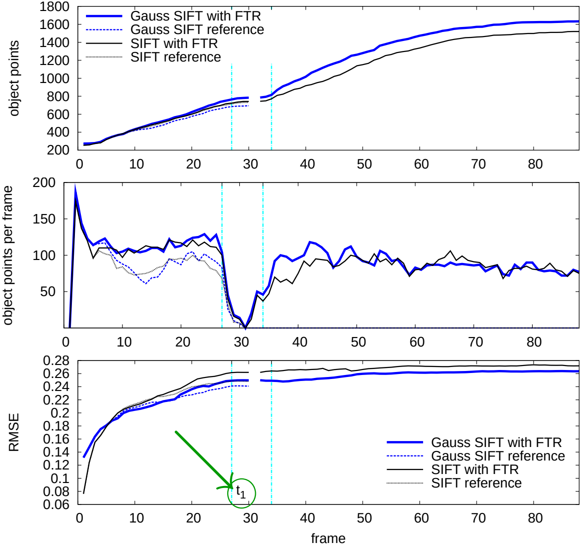
- temporary occlusions
- less object pts for FTR
- more object pts for Gauss SIFT



Bellevue Sequence

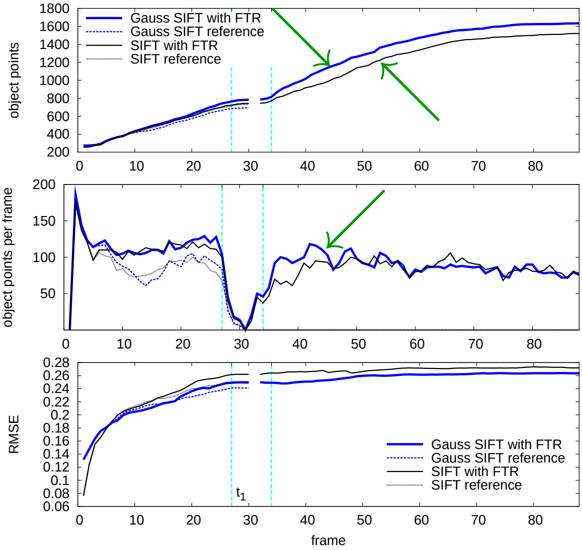
- temporary occlusions
- less object pts for FTR
- more object pts for Gauss SIFT
- RMSE(FTR) $>$ RMSE(ref)
- RMSE(Gauss SIFT) $<$ RMSE(SIFT)

Experimental Results



Lift Sequence

- temporary Occlusion
- reference fails



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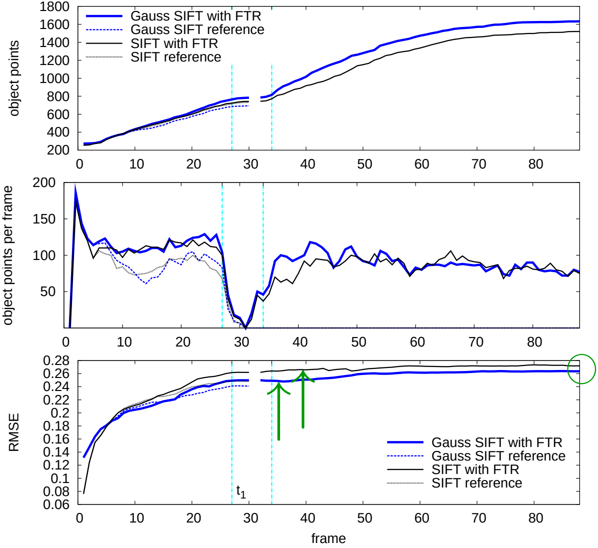

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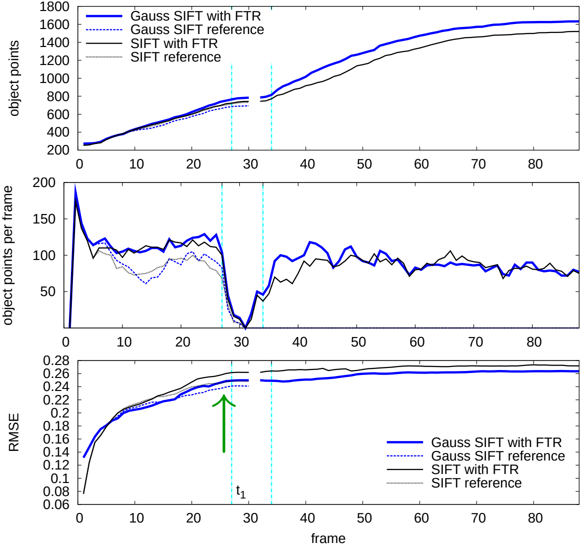
Experimental Results



Lift Sequence

- temporary Occlusion
- reference fails
- more object pts for Gauss SIFT
- RMSE(Gauss SIFT) < RMSE(SIFT)
- RMSE(FTR) > RMSE(ref)

Example: *Lift* sequence [1]

1. Input sequence (15 fps)
2. Result: SIFT reference
3. Result: SIFT with FTR
4. Result: Gaussian SIFT with FTR

[1] http://www.youtube.com/watch?v=q2EQXR5RXrA

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Future Work:

- Exploit occlusion image locations for further scene understanding

http://www.tnt.uni-hannover.de/staff/cordes/

http://www.tnt.uni-hannover.de/project/motionestimation/