Temporally Consistent High Frame-Rate Upsampling with Motion Sparsification

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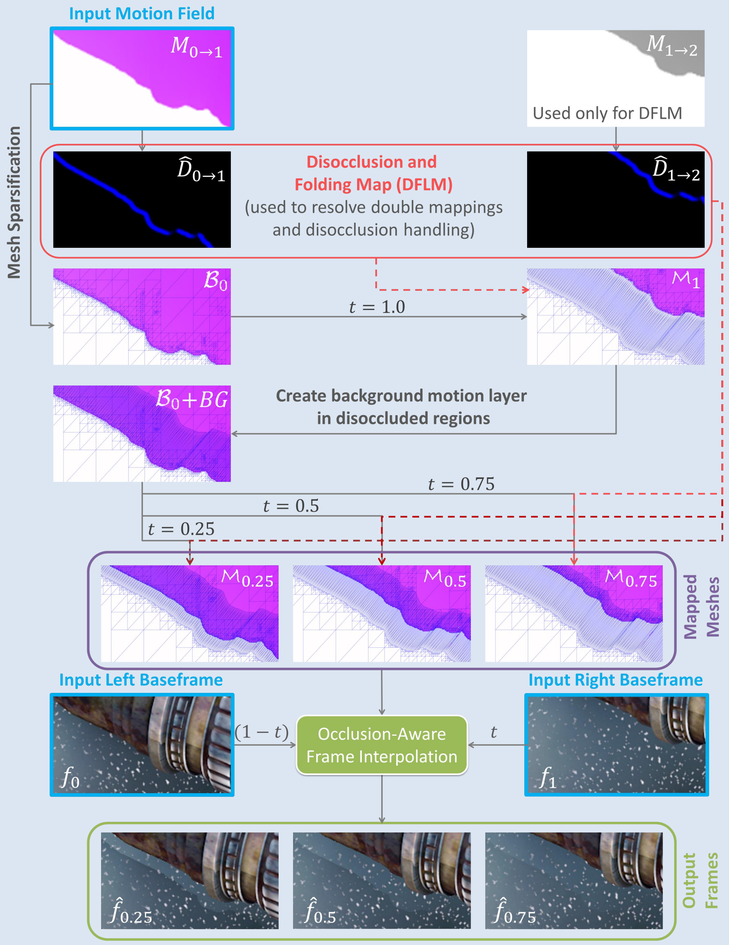
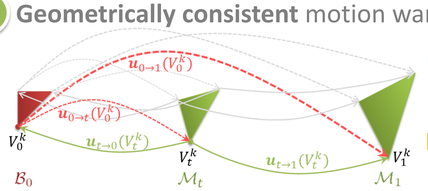
Overview

:: We propose a **mesh-based** temporal frame interpolation (TFI) method which produces **temporally consistent** interpolated frames, which is particularly important for **high upsampling factors.**



Highlights

- **Bidirectional, occlusion-aware frame interpolation**
- **Geometrically consistent** motion warping operations



Motion Inversion

$$u_{t\to0}(V_t^p) = -u_{0\to t}(V_0^p)$$

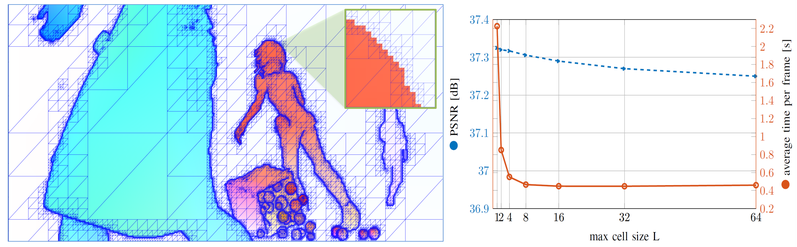
Motion Inference

$$u_{t\to1}(V_t^p) = u_{0\to1}(V_0^p) + u_{t\to0}(V_t^p)$$

- **Temporally consistent motion**
  → Particularly important for **higher upsampling factors** (>2)
- **Adaptive mesh** size for **faster** processing

Triangular Mesh Sparsification

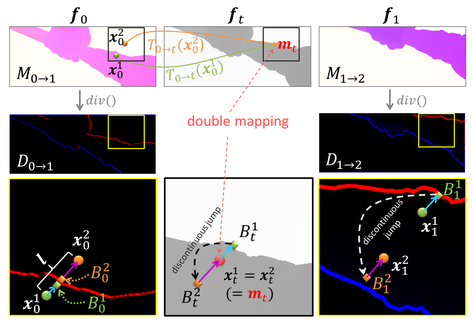
:: Adaptive mesh size based on smoothness of the motion field.



Allowing for larger triangle sizes in regions of smooth (affine) motion **reduces the processing time by 75%**, with a **trivial impact on PSNR**.

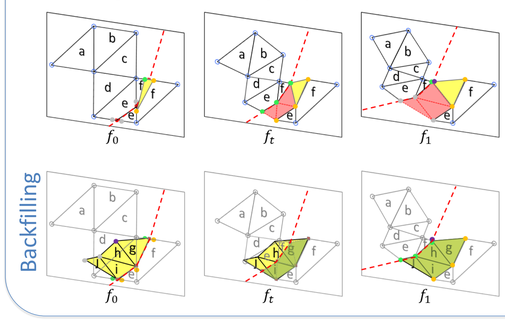
Handling of Regions around Moving Objects

:: Leading side of moving objects → **Double mappings**



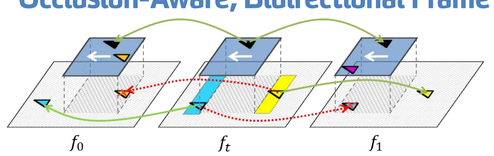
Double mappings are **resolved** by observing that **motion discontinuities displace** with the **foreground** object.

:: Trailing side of moving objects → **Disocclusions** (i.e., holes)



The proposed **motion backfilling** procedure creates **temporally consistent motion** in **disoccluded regions**.

Occlusion-Aware, Bidirectional Frame Prediction



Visibility Mask

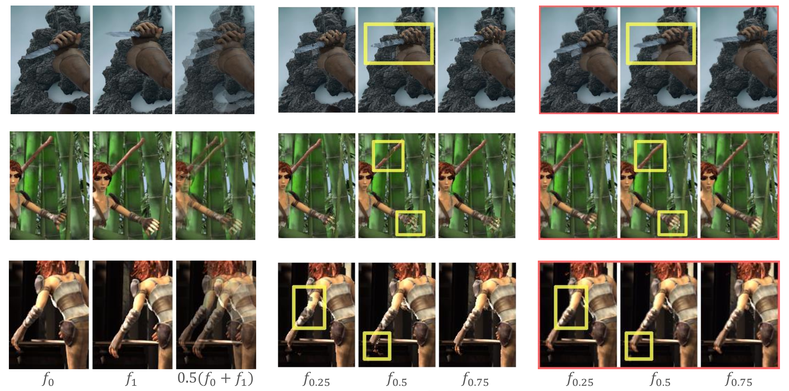
$$V_t^j[\boldsymbol{m}] = \begin{cases} 1 & ID_t[\boldsymbol{m}] = ID_j[\boldsymbol{m} + M_{t\to j}[\boldsymbol{m}]] \\ 0 & otherwise \end{cases}$$

TFI based on triangle visibility

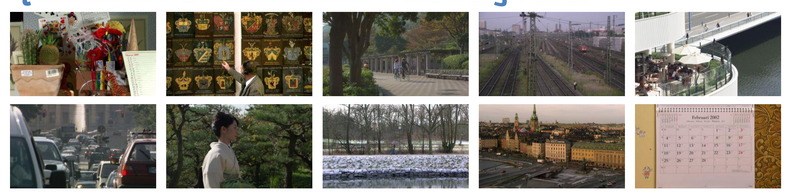
$$f_t[\boldsymbol{m}] = \begin{cases} (1-t)\boldsymbol{f}_{0\to t}[\boldsymbol{m}] + t\boldsymbol{f}_{1\to t}[m] & V_t^0[\boldsymbol{m}] = V_t^1[\boldsymbol{m}] \\ \boldsymbol{f}_{j\to t}[\boldsymbol{m}] & otherwise \end{cases}$$

Triangle ID consistency checking can be used to **assess the visibility** of regions in the target frame.

Qualitative Evaluation of Temporal Consistency



Quantitative Evaluation and Processing Times



Method	PSNR	ME [s]	FI [s]	ME+FI	
Jeong [1]	35.1	410.2	499	909.1	Block based
Veselov [2]	35.7	32.4	2.1	34.5	Block based
Lu [3]	35.1	96.2	18.1	114.3	Block based
BOA-TFI† [4]	37.1	355.4	8.2	363.6	Optical flow
BAM-TFI†	**37.3**	355.4	**0.5**	355.9	Optical flow
BAM-TFI*	36.5	**7.0**	**0.5**	**7.5**	Optical flow

† Motion estimated using MDP flow [5] *Motion estimated using EPIC flow [6]

Optical flow (for TFI)

- High quality, no block artefacts
- Competitive processing times

Conclusions and Future Work

Propose a TFI method with Base-Anchored Mesh (BAM-TFI)

- **Motion** Information **linked across frames** → **Temporally consistent** frame interpolation, in particular **around moving objects**.
- **Mesh sparsification reduces** computational **complexity** with **no visible impact** on the interpolated frames.

:: Incorporation of **higher-order motion** models for better **prediction**
:: **Integration** of BAM-TFI into a **video compression scheme**

References

[1] S. Jeong, C. Lee, and C. Kim,"Motion-compensated frame interpolation based on multihypothesis motion estimation and texture optimization," IEEE Trans. on Image Processing, vol. 22, no. 11, 2013.
[2] A. Veselov and M. Gilmutdinov, "Iterative Hierarchical True Motion Estimation for Temporal Frame Interpolation," IEEE Int. Workshop on Multimedia Signal Processing (MMSP), 2014.
[3] Q. Lu, N. Xu, and X. Fang, "Motion-Compensated Frame Interpolation with Multiframe based Occlusion Handling," Journal of Display Technology, vol. 11, no. 4, 2015.
[4] D. Rüfenacht, R. Mathew, and D. Taubman, "Occlusion-Aware Temporal Frame Interpolation in a Highly Scalable Video Coding Setting," APSIPA Trans. Signal and Information Proc. (ATSIP), 2016.
[5] L. Xu, J. Jia, and Y. Matsushita, "Motion detail preserving optical flow estimation," IEEE Trans. On Pattern Analysis and Machine Intelligence (PAMI), pp. 1744–1757, 2012.
[6] J. Revaud, P. Weinzaepfel, Z. Harchaoui, and C. Schmid, "Epicflow: Edge-preserving interpolation of correspondences for optical flow," IEEE Conf. Computer Vision and Pattern Recognition (CVPR), 2015.