3D Models in Motion Compensation

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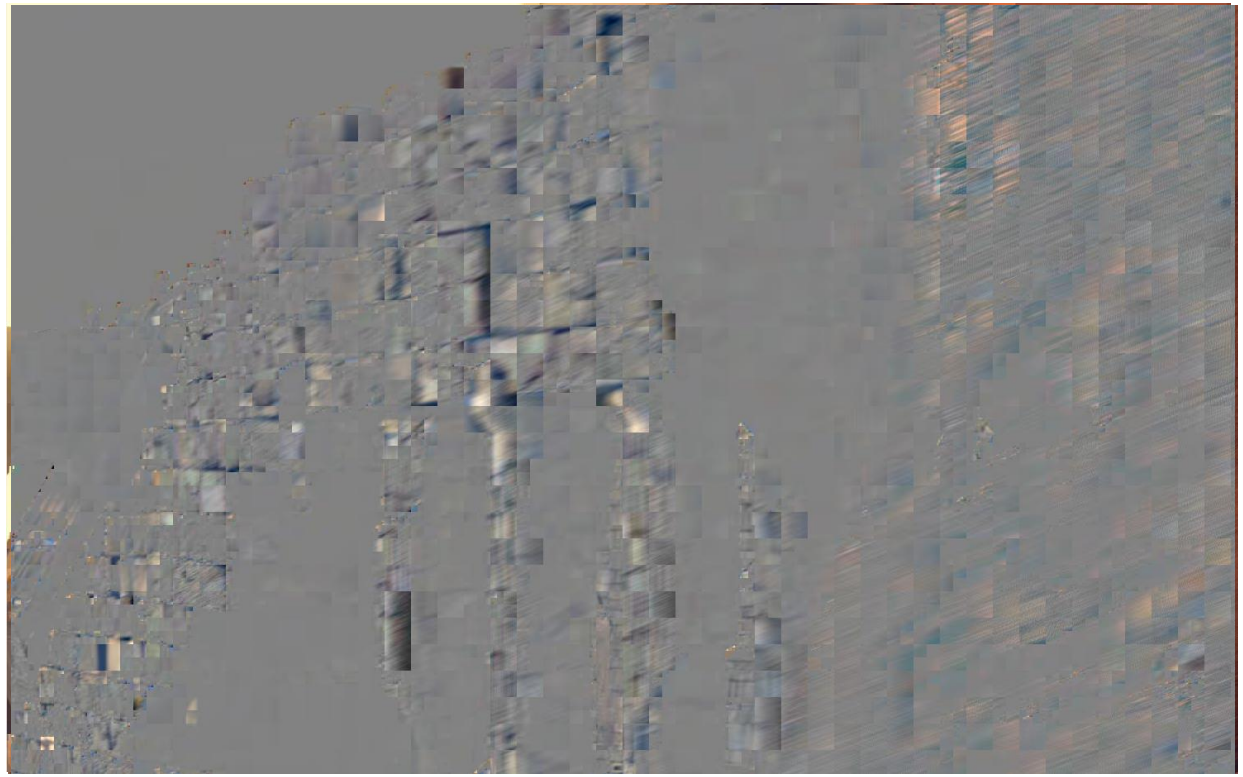
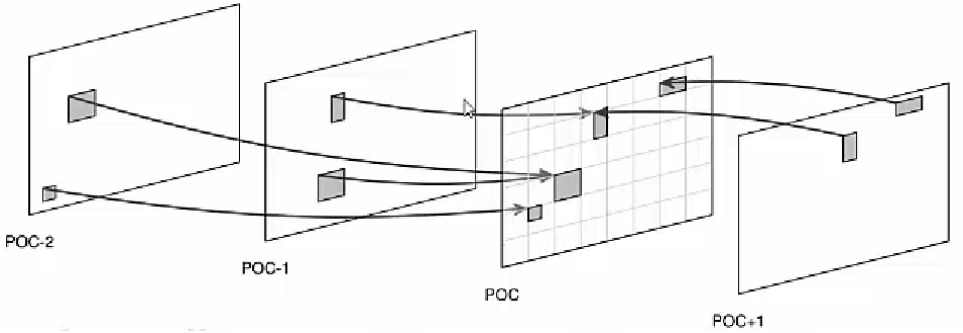
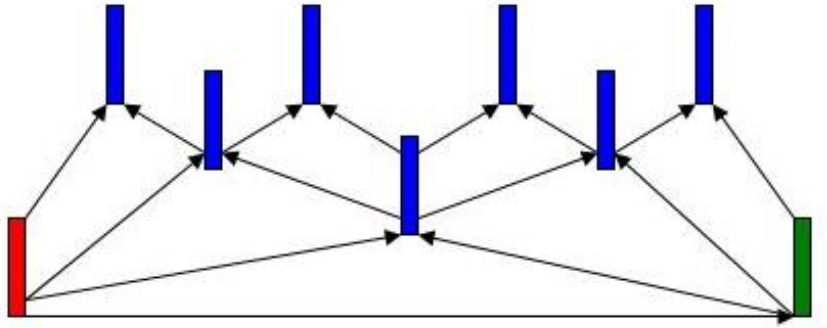
Outline

- Introduction to the main idea
- Structure from Motion (SfM)
- Multi-View Reconstruction (MVR)
- Virtual view synthesis for 2D frame prediction
- Coding results
- Conclusion

Introduction to the main idea







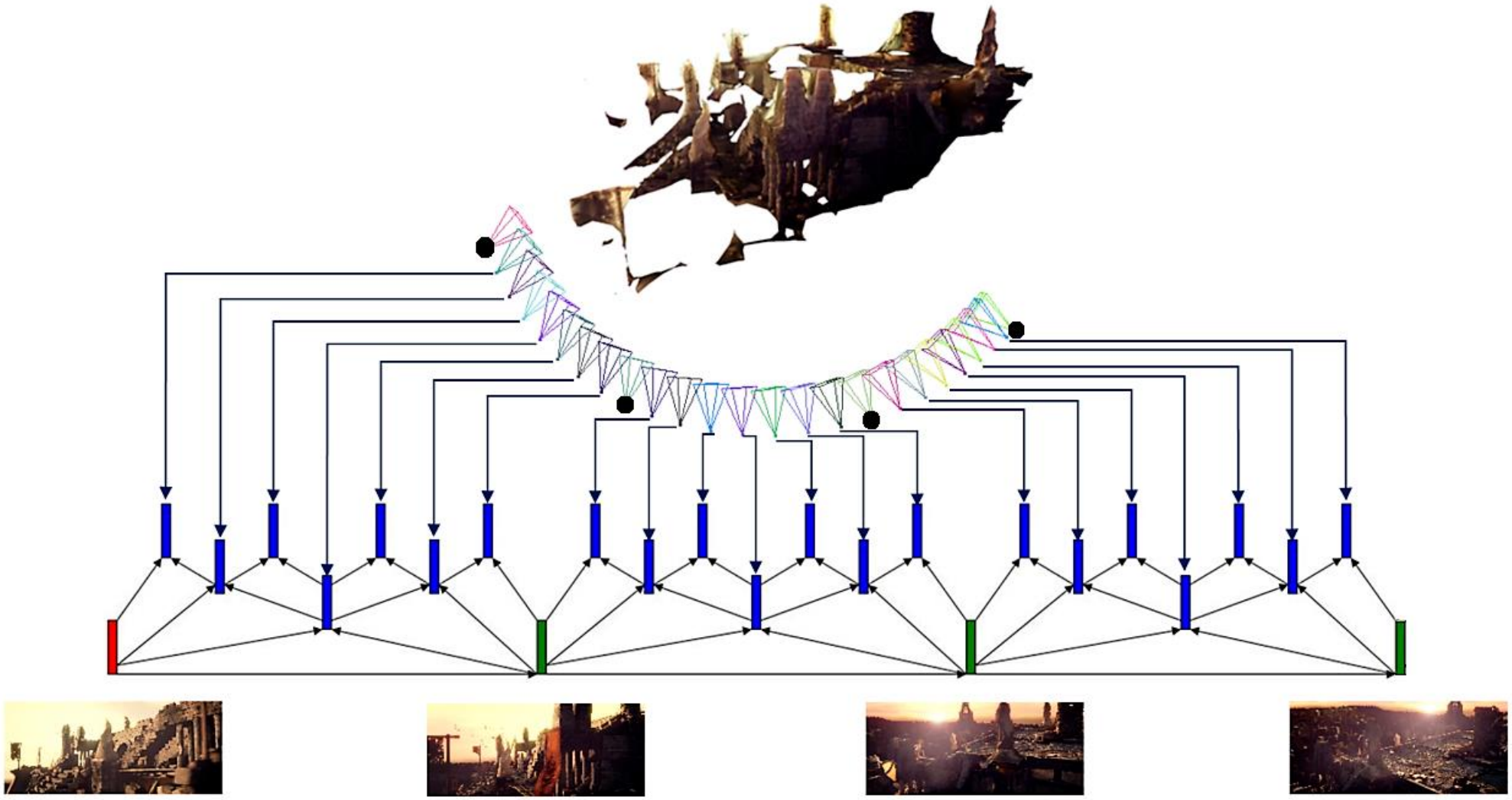
Introduction to the main idea

- Target Sequences (moving camera)

Introduction to the main idea

- 3D model based frame prediction
  - **B-Frame Prediction**
  - Key-Frame Prediction

Introduction to the main idea



Introduction to the main idea

- 3D model based frame prediction
  - B-Frame Prediction
  - **Key-Frame Prediction**

Introduction to the main idea

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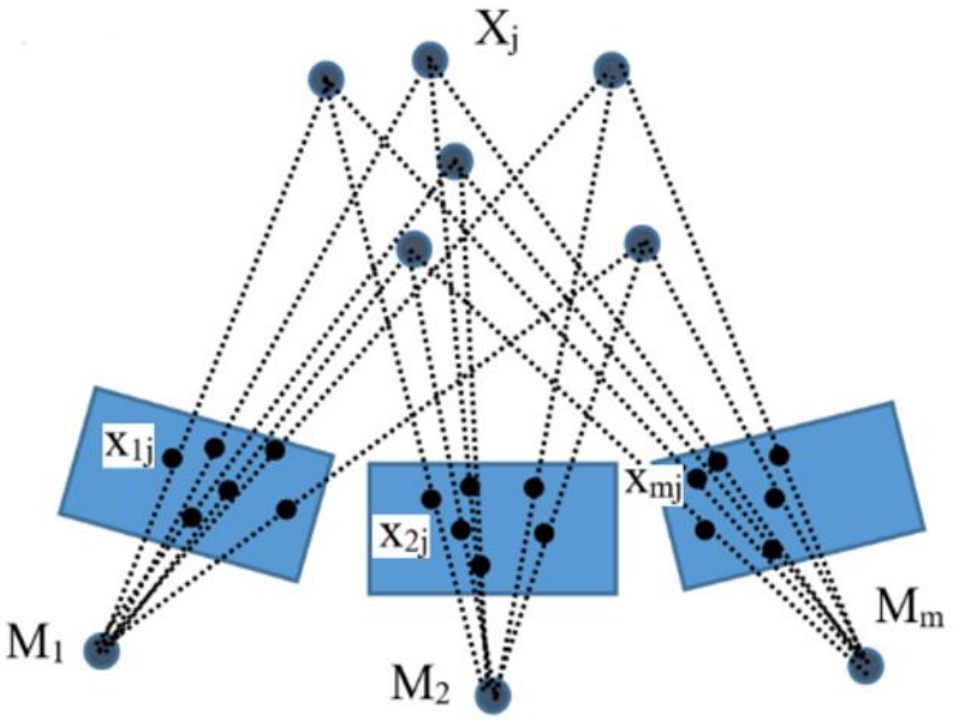
Structure from Motion (SfM)

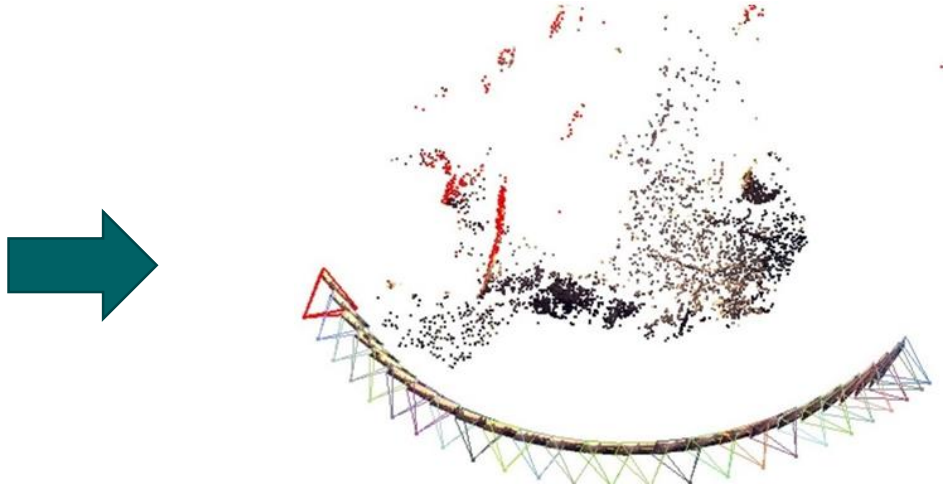
- Structure from Motion (SfM) [1]

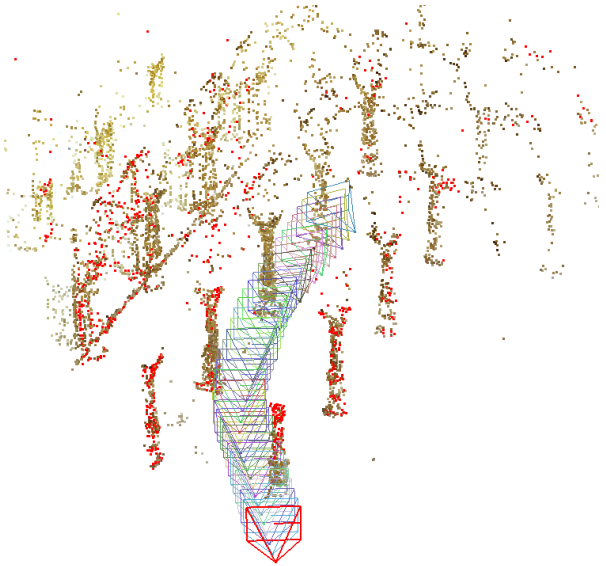
$$x_{ij} = M_i X_j, \qquad i = 1, \dots, m \;\; j = 1, \dots, n$$

- How to solve SfM?
  - Feature extraction & Finding corresponding points
  - Finding Fundamental matrix F (${x'}^T F x = 0$)
  - Estimating projective cameras
  - Triangulating
  - Bundle Adjustment

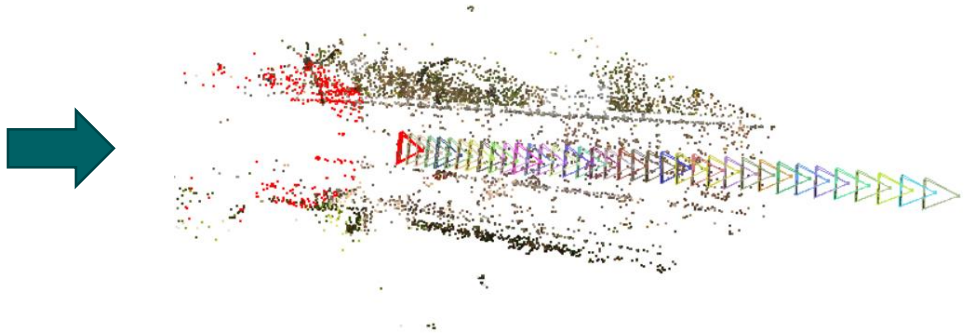


[1] R. Hartley and A. Zisserman, “Multiple view geometry in computer vision“, second edition, Cambridge press, 2013.

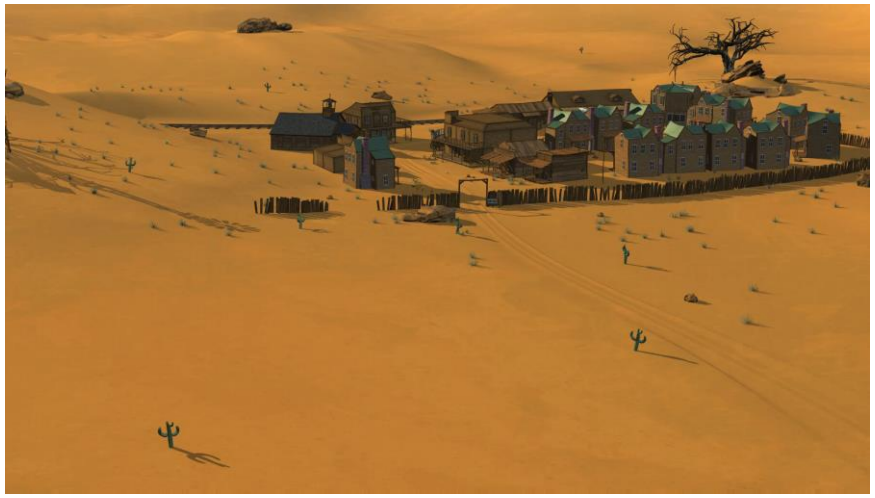


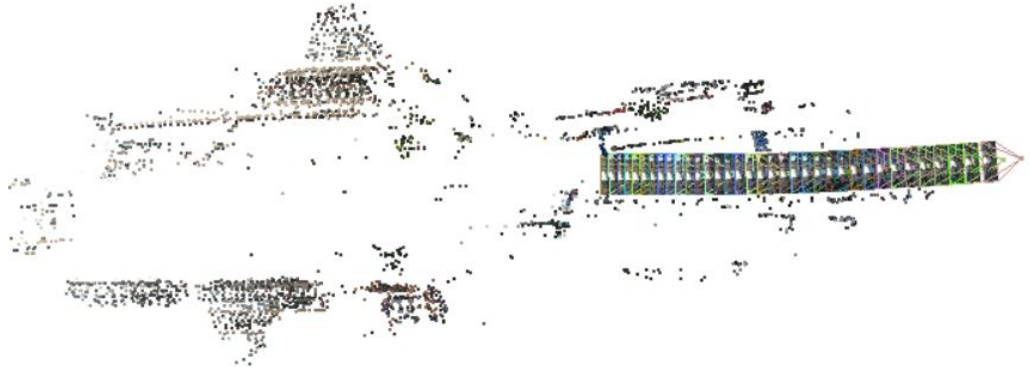


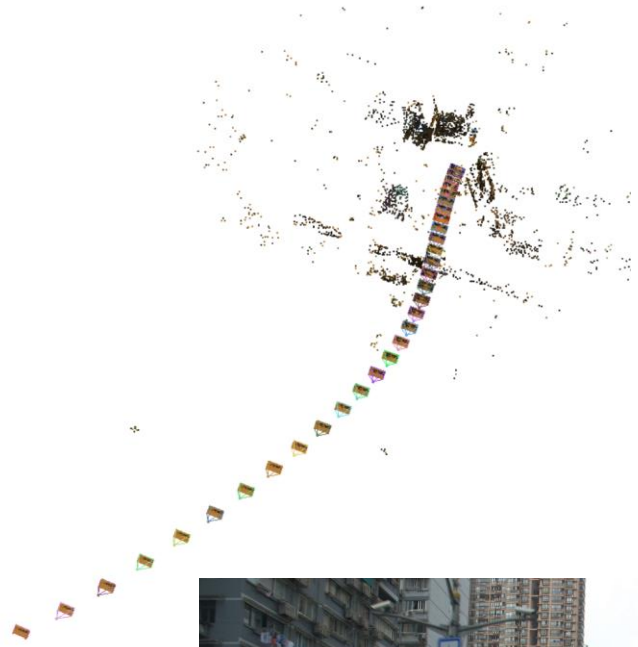
SfM Results

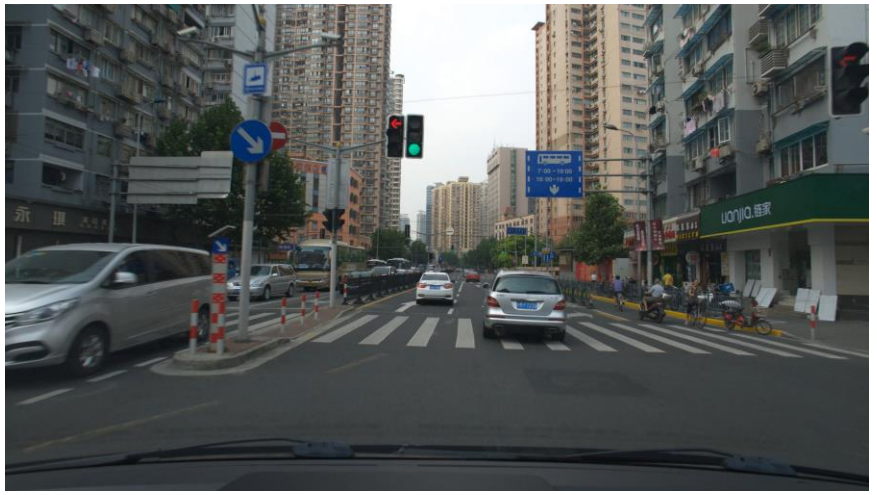


SfM Results









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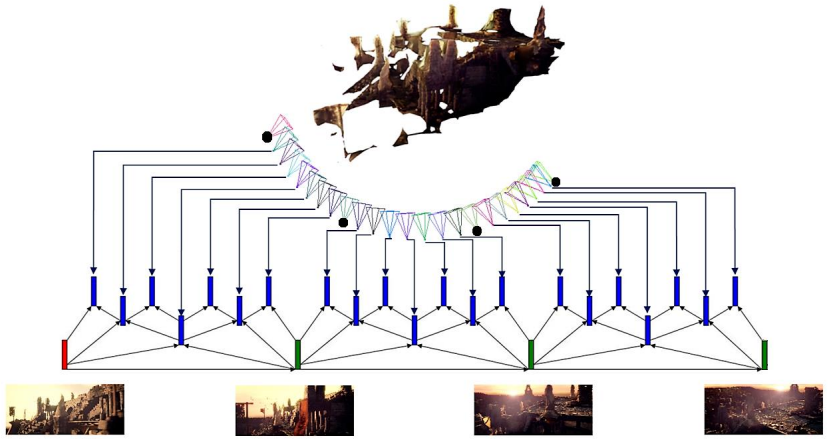
Multi-View Reconstruction (MVR)

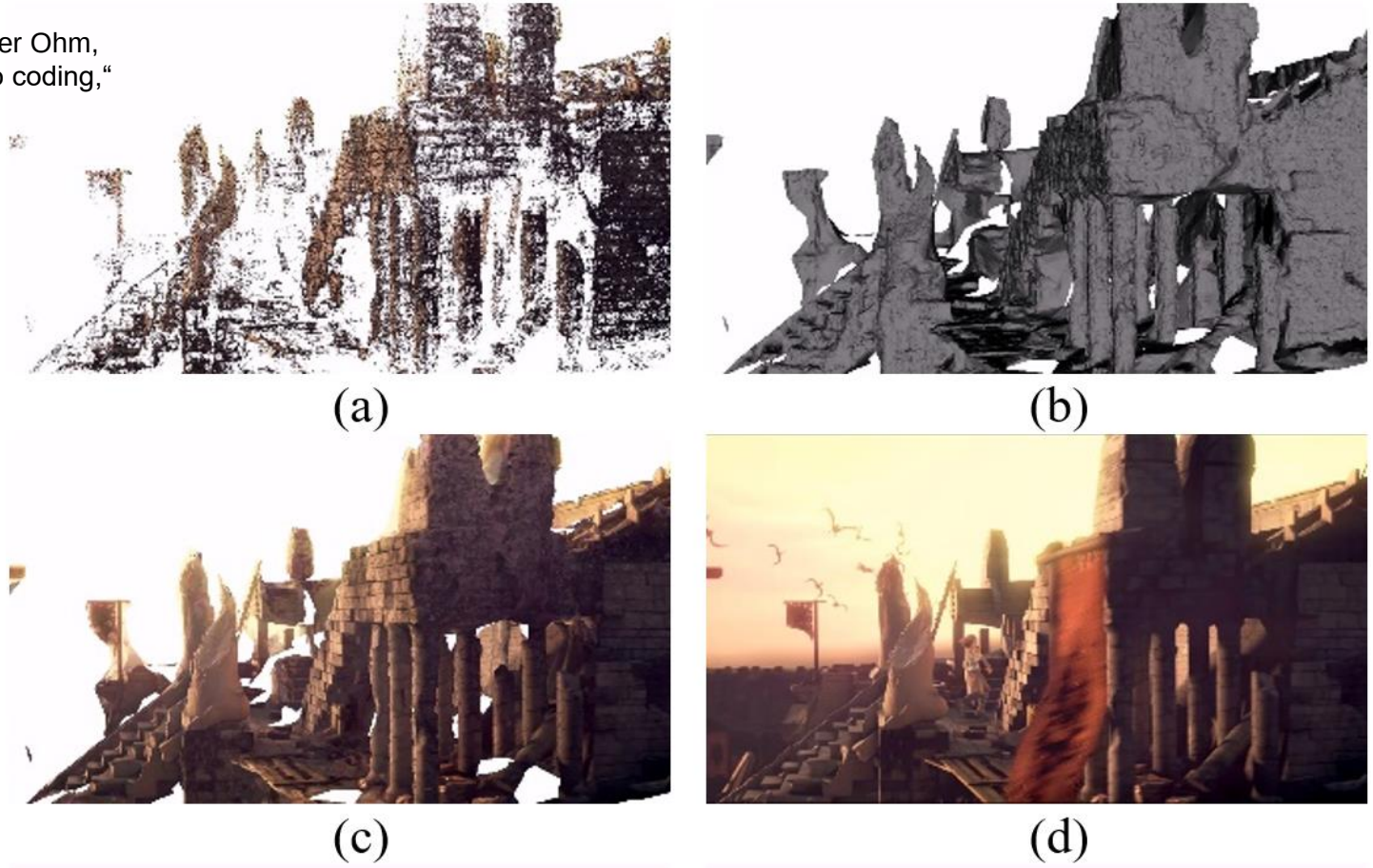
- Generating a quasi-dense point cloud
- Visibility based surface reconstruction
  - Delaunay tetrahedralization
  - Surface optimization with minimum s-t cut [2])
- The variational refinement of mesh to optimize its photo-consistency (Minimizing reprojection error)

[2] H. Vu, P. Labatut, J. Pons and R. keriven, “High accuracy and visibility-consistent dense multiview stereo”, IEEE Transaction on pattern analysis and machine intelligence, vol. 34, no. 5, 2012.

Application in Video Coding?

[3] Hossein B. Golestani, Jens Schneider, Mathias Wien and JensRainer Ohm, „Point cloud estimation for 3D structure based frame prediction in video coding,“ ICME 2017, Hong Kong.





(a) quasi-dense point cloud, (b) shaded surface, (c) textured surface and (d) ground thruth

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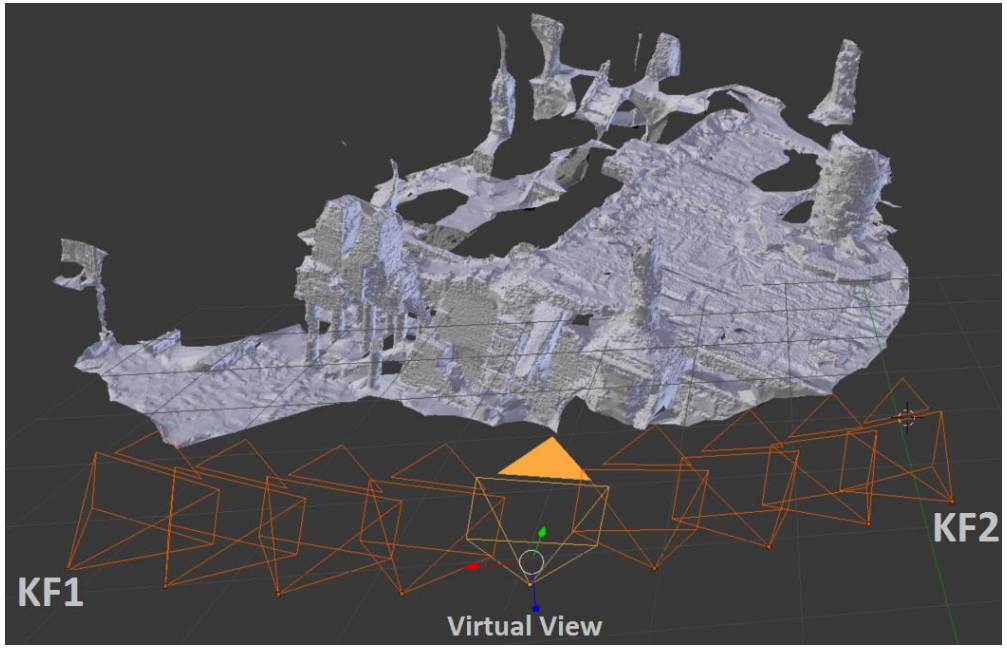
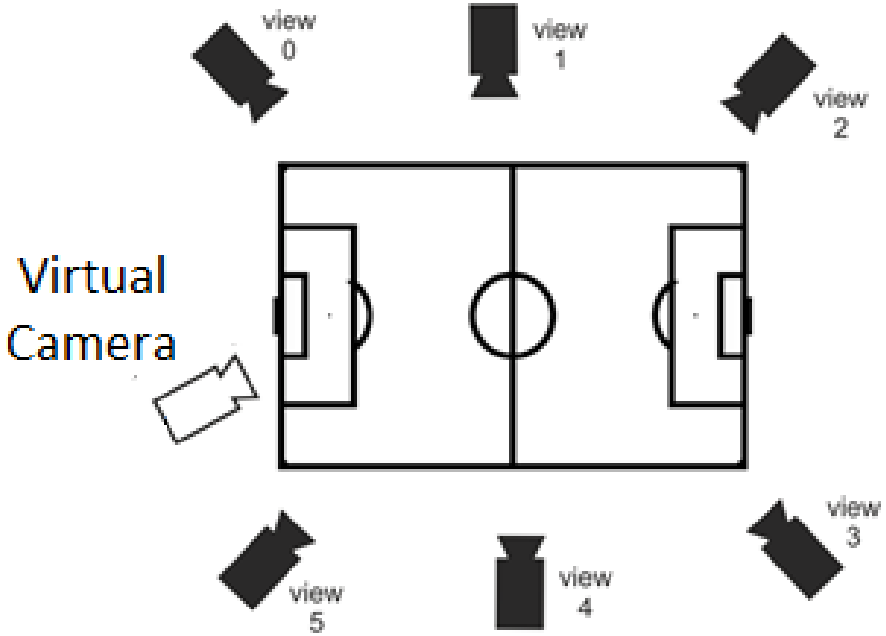
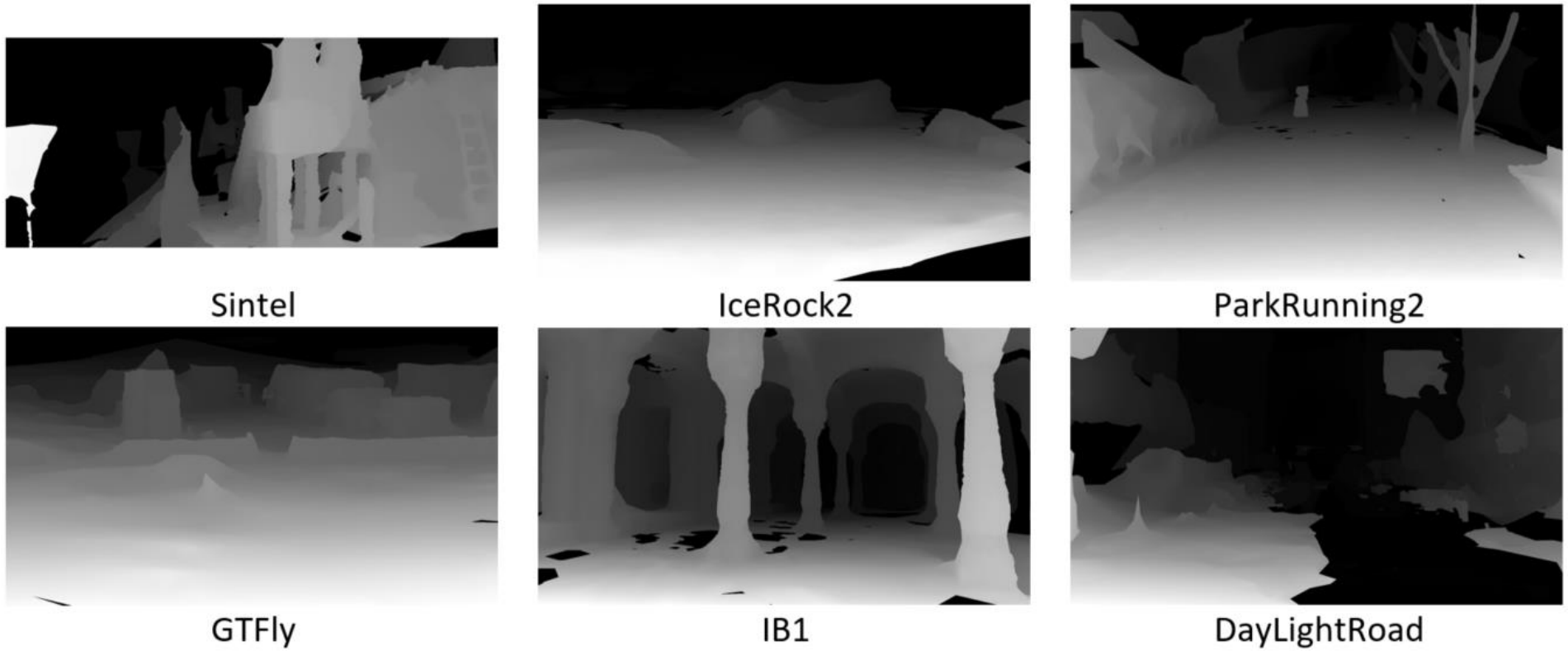
New method for frame prediction: Virtual View Synthesis

- How to improve the quality of predicted frame? Virtual View synthesis
- What does it need?
  - Left and right views
  - Camera parameters for left, right and virtual cameras
  - Depth information of left and right views (depthmaps, Z-min & Z-max)





Estimated Depthmaps



Virtual View Synthesis

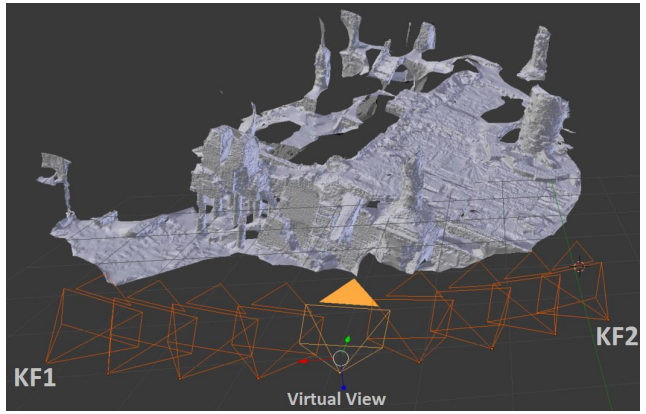
- Steps:
  - Estimating the depthmaps of the virtual view from KFs‘ depthmaps
    - Finding a homography transformation between real and virtual views for each depth level

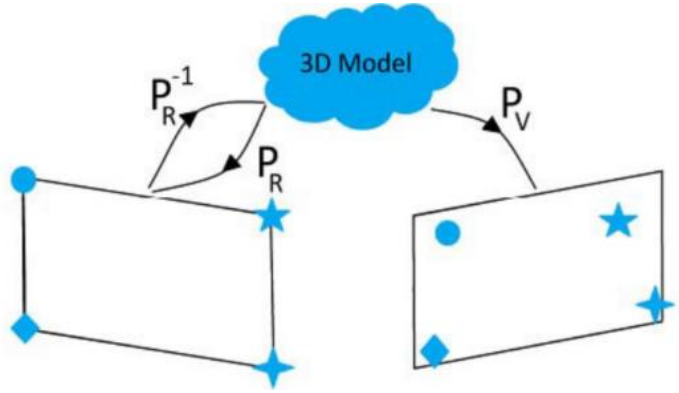
$$X_V[i] = P_V P_R^{-1} X_R[i], \quad i = depth\,levels$$

  - Synthesizing the virtual view by warping textures from left and right key-frames

$$[h, w, 1]^T = H^{-1}[i] \times [u, v, 1]^T, \quad [u, v]: virtual\,view, \quad [h, w]: real\,view$$

  - Blending the synthesized view from left and right

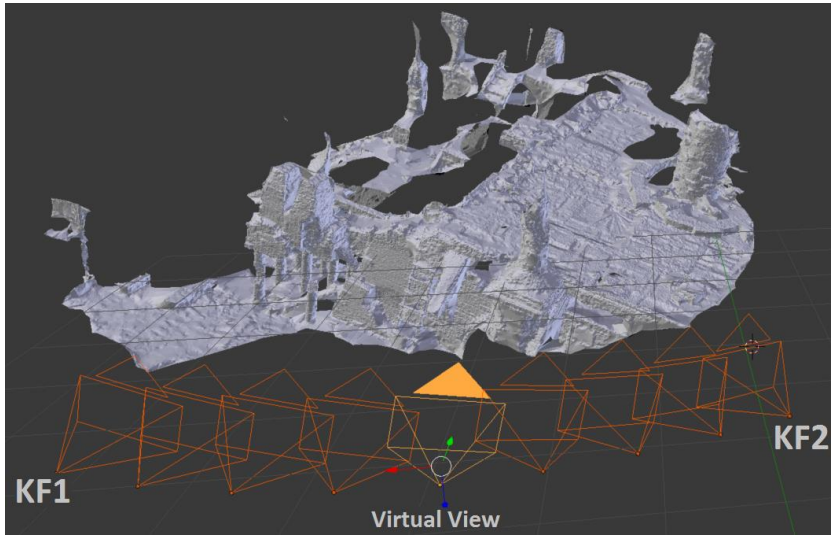




Synthesized frames

(a) Ground Truth

(b) Synthesized (virtual view)



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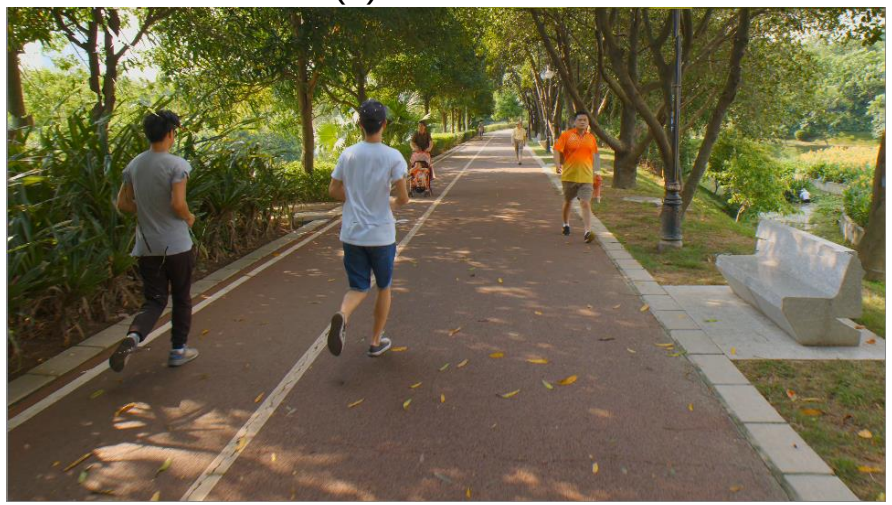
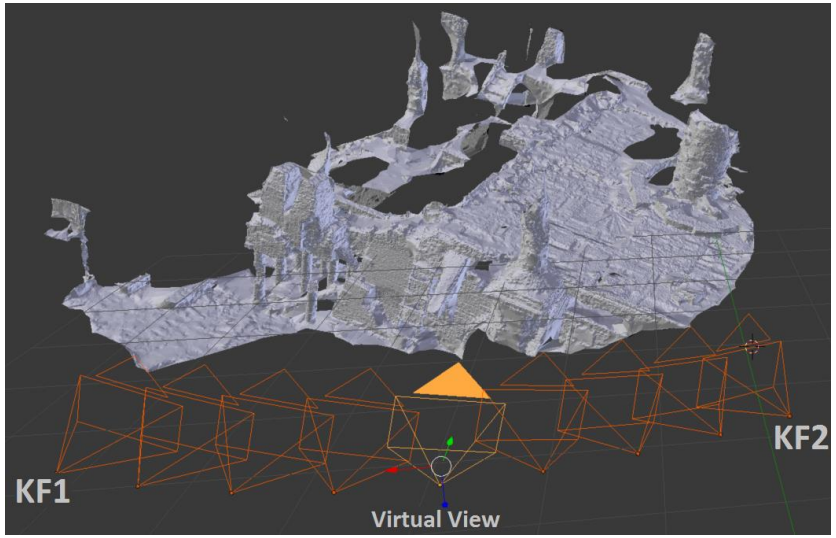


(b) Synthesized (virtual view)



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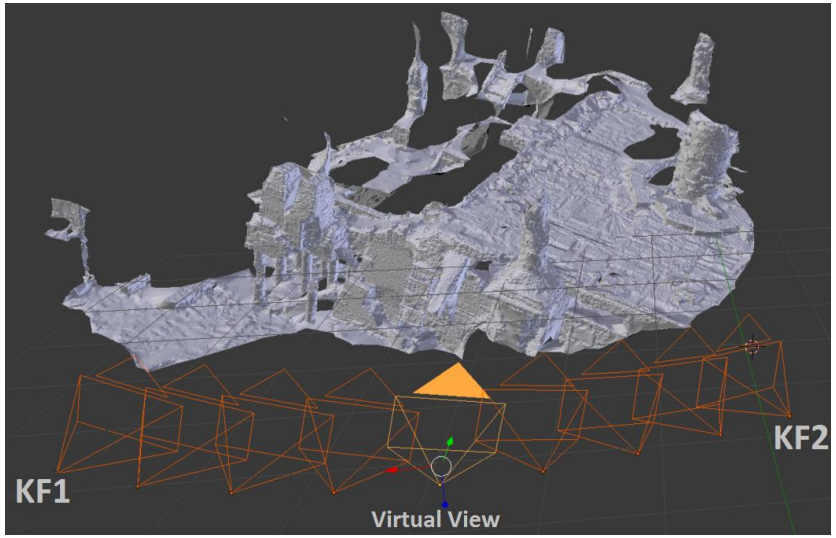

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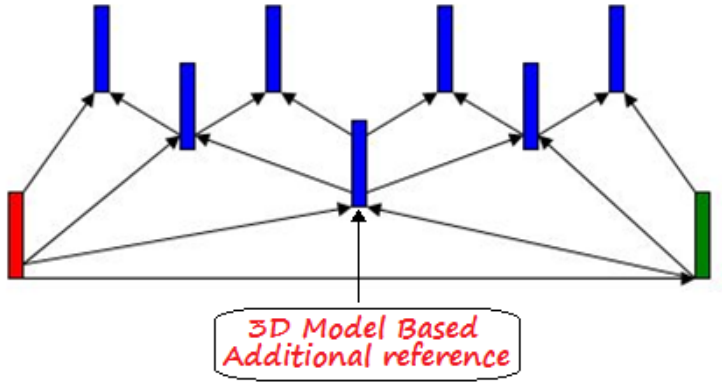
SfM based frame prediction in Video Coding

- HEVC test Model (HM 16.7)
  - SfM-based prediction is added to L0 and L1
  - The encoder can choose between
    - its built-in reference images
    - The offered SfM-based prediction
  - QP: 25, 29, 33 and 37, Random Acess main profile

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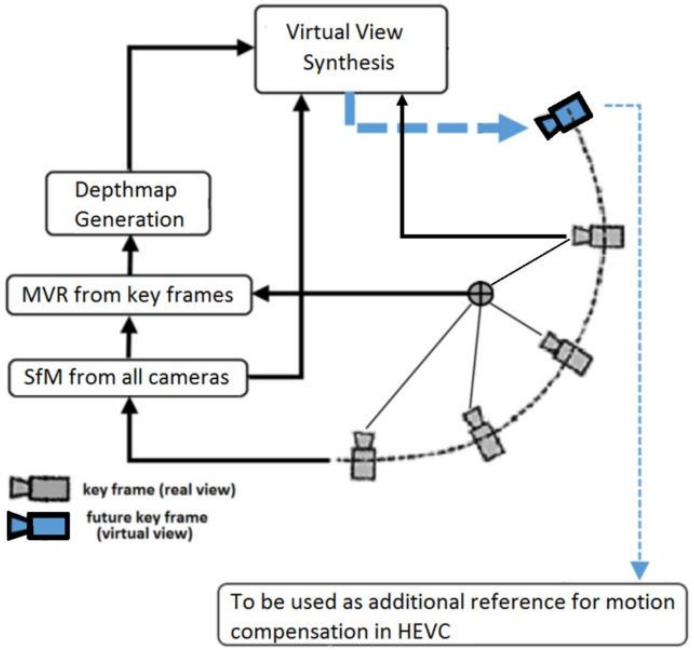
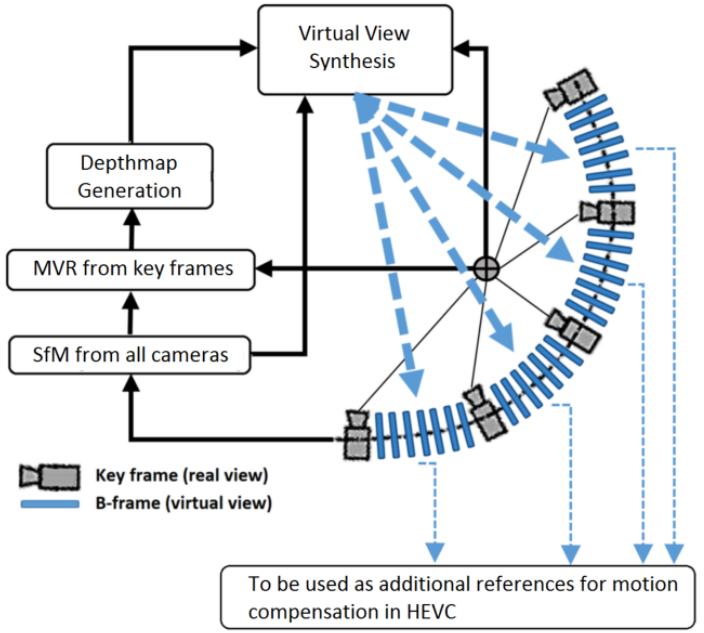
POC    24 TId: 0 ( B-SLICE, nQP 38 QP 38 )      48048 bits [Y 39.0652 dB    U 46.8478 dB    V 47.1814 dB] [ET   158 ] [L0 16 8 24(AddRef) ] [L1 16 8 24(AddRef) ]
POC    20 TId: 1 ( B-SLICE, nQP 39 QP 39 )       6552 bits [Y 39.3872 dB    U 46.9528 dB    V 47.2622 dB] [ET   149 ] [L0 16 12 20(AddRef) ] [L1 24 16 20(AddRef) ]
POC    18 TId: 2 ( B-SLICE, nQP 40 QP 40 )       3576 bits [Y 38.7807 dB    U 46.8727 dB    V 47.1718 dB] [ET   161 ] [L0 16 12 18(AddRef) ] [L1 20 24 18(AddRef) ]
POC    17 TId: 3 ( B-SLICE, nQP 41 QP 41 )        992 bits [Y 38.8425 dB    U 46.8946 dB    V 47.2129 dB] [ET   144 ] [L0 16 18 17(AddRef) ] [L1 18 20 17(AddRef) ]
POC    19 TId: 3 ( B-SLICE, nQP 41 QP 41 )       1464 bits [Y 38.5592 dB    U 46.8896 dB    V 47.1888 dB] [ET   158 ] [L0 18 16 19(AddRef) ] [L1 20 24 19(AddRef) ]
POC    22 TId: 2 ( B-SLICE, nQP 40 QP 40 )       3232 bits [Y 39.1846 dB    U 46.9233 dB    V 47.1872 dB] [ET   145 ] [L0 20 16 22(AddRef) ] [L1 24 20 22(AddRef) ]
POC    21 TId: 3 ( B-SLICE, nQP 41 QP 41 )       1576 bits [Y 38.8811 dB    U 46.9153 dB    V 47.1979 dB] [ET   158 ] [L0 20 16 21(AddRef) ] [L1 22 24 21(AddRef) ]
POC    23 TId: 3 ( B-SLICE, nQP 41 QP 41 )       1656 bits [Y 38.7014 dB    U 46.8517 dB    V 47.1399 dB] [ET   144 ] [L0 22 20 23(AddRef) ] [L1 24 22 23(AddRef) ]
POC    32 TId: 0 ( P-SLICE, nQP 37 QP 37 )     383656 bits [Y 38.9582 dB    U 46.6173 dB    V 46.8710 dB] [ET   226 ] [L0 32(AddRef) 32(AddRef) 32(AddRef) ] [L1 ]
```

Seq.	Sintel	IceRock2	GTFly	ParkRunning2	DayLightRoad	IB1
BD-Rate (%)	-2.21	-10.76	-6.64	-2.55	-2.80	-5.91
BD_PSNR (dB)	+0.08	+0.32	+0.19	+0.08	+0.04	+0.07

Conclusion

- An SfM-based frame prediction scheme has been presented.
- SfM for camera calibration
- MVS for surface reconstruction.
- Virtual view synthesis for synthesizing novel views.
- SfM-based prediction is added to reference lists (L0 and L1)
- So far, 2% to 10% bitrate reduction is achieved.
- Estimating better depthsmaps will improve results.





Vielen Dank
für Ihre Aufmerksamkeit