Christian Richardt

360° (Stereo) Panoramas

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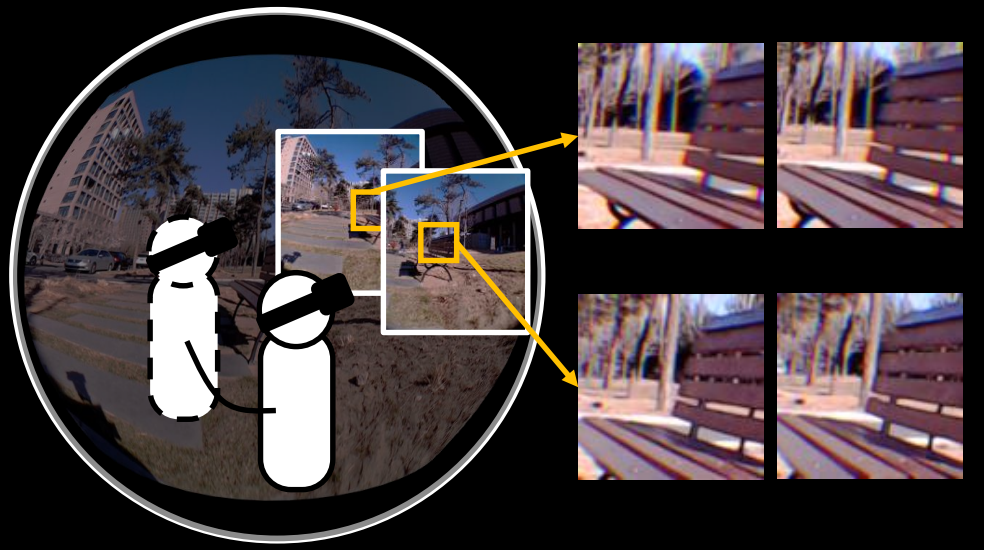
UNIVERSITY OF BATH

360° (Stereo) Panoramas

1. 360° panoramas
   - alignment + stitching [Brown & Lowe 2007]
   - parallax-aware stitching [Zhang & Liu, 2014]
2. Stereo panoramas
   - Omnistereo [Peleg et al. 2001]
   - MegaStereo [Richardt et al. 2013]
3. Towards 6-DoF with motion parallax
   - Parallax360 [Liu et al. 2018]
   - MegaParallax [Bertel et al. 2019]



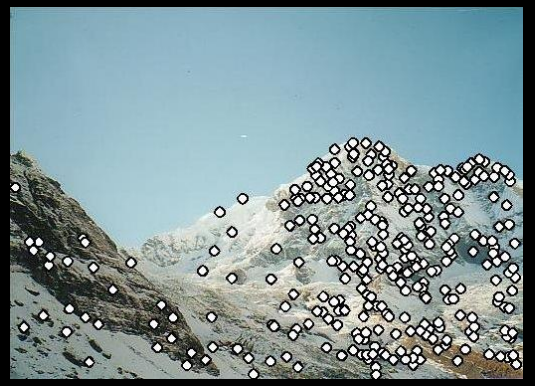
Luo et al., TVCG 2018

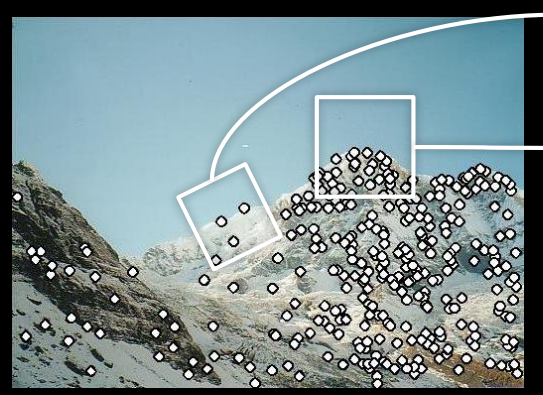
Feature matching

1. **Detection:**
   Identify the interest points

2. **Description:**
   Extract vector feature descriptor surrounding each interest point.

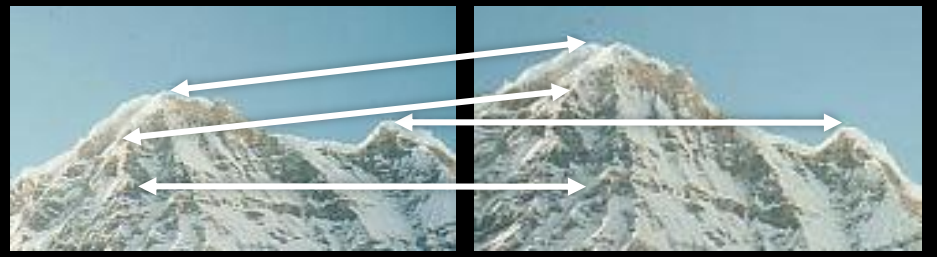
3. **Matching:**
   Determine correspondence between descriptors in 2 views





$$\mathbf{x}_1 = \left[x_1^{(1)}, \ldots, x_d^{(1)}\right]$$

$$\mathbf{x}_2 = \left[x_1^{(2)}, \ldots, x_d^{(2)}\right]$$



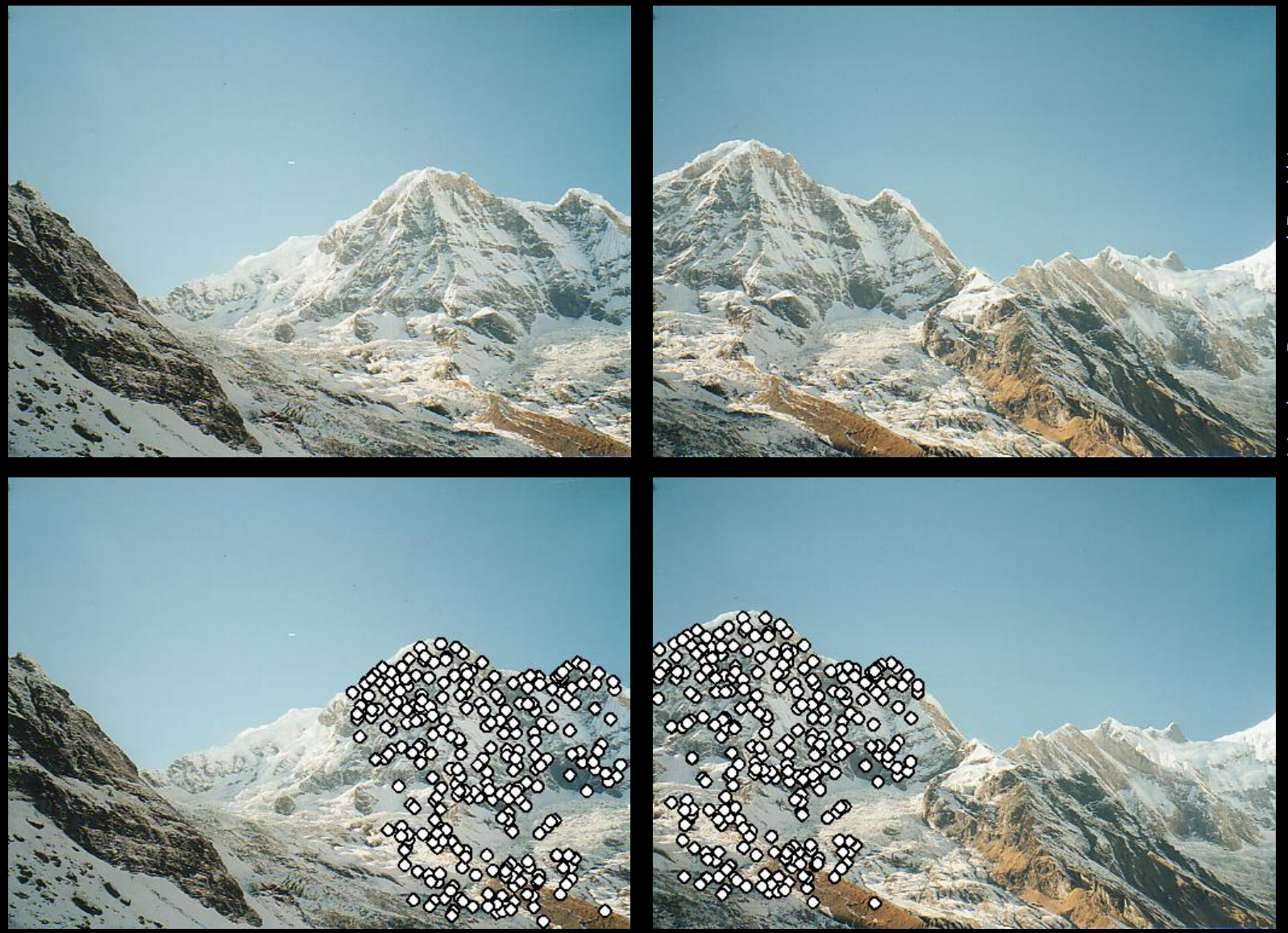
Slide by Kristen Grauman

SIFT features

Matthew Brown and David Lowe

Slide by Matthew Brown

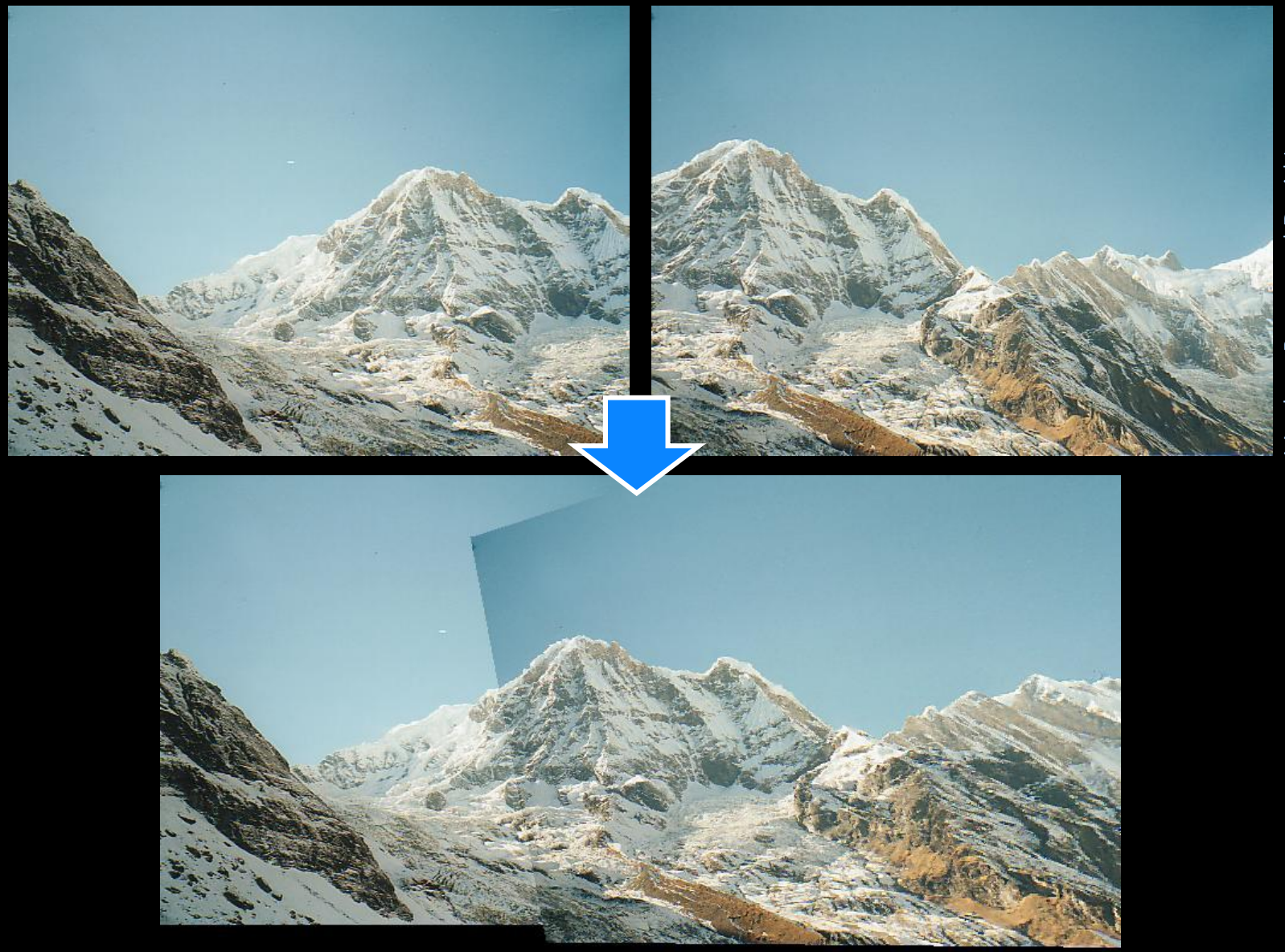
Matched SIFT features



Matthew Brown and David Lowe

Slide by Matthew Brown

Aligned images



Matthew Brown and David Lowe

Slide by Matthew Brown

Image alignment

Slide by Matthew Brown

Image blending

- Multi-band blending [Burt & Adelson, TOG 1983]

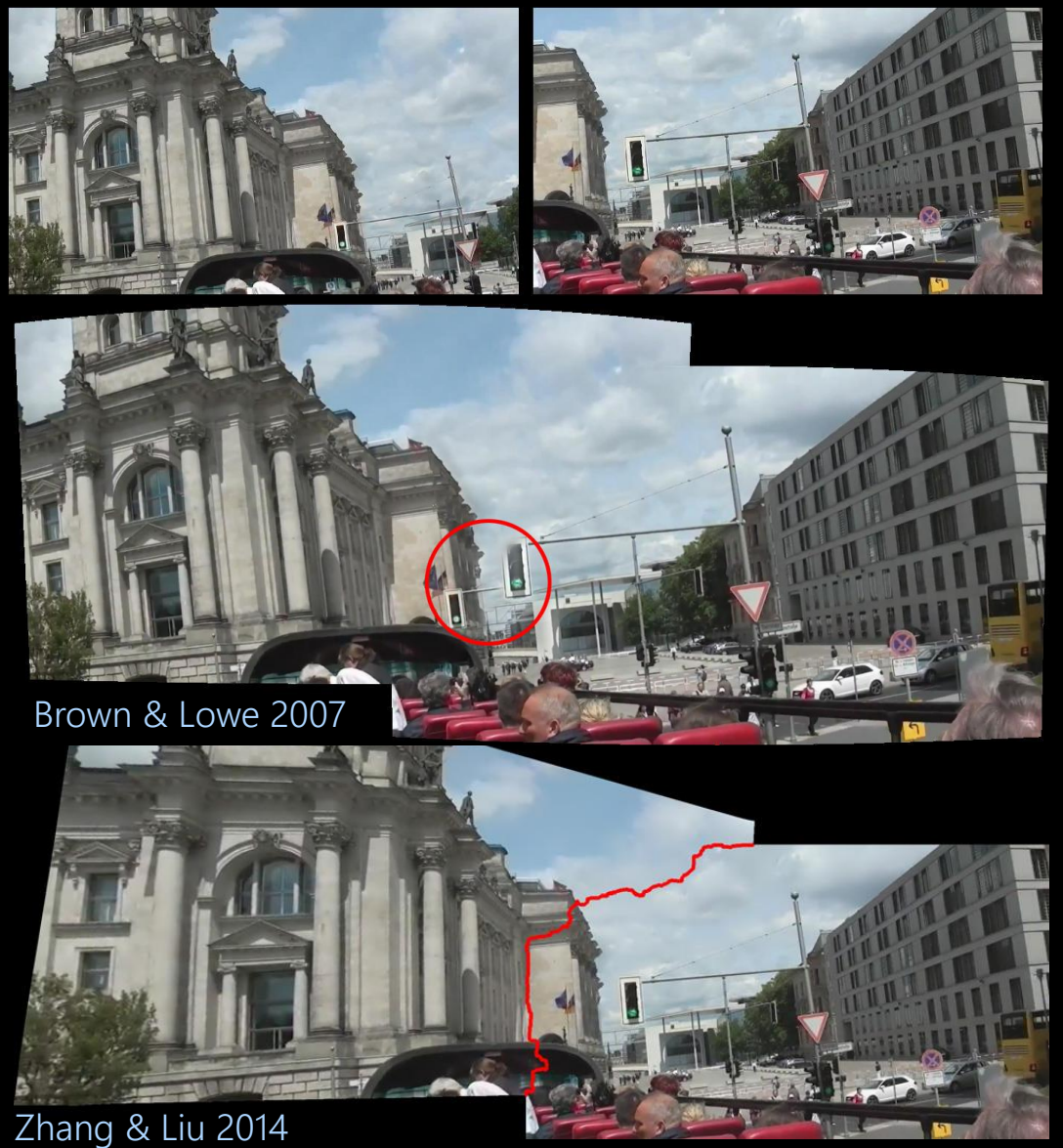
Automatic Panoramic Image Stitching using Invariant Features
Matthew Brown & David G. Lowe
International Journal of Computer Vision, 2007

Image alignment and stitching: a tutorial
Richard Szeliski
Foundations and Trends in Computer Graphics and Vision, 2006

Slide by Matthew Brown

Parallax-aware stitching

- image alignment generally relies on homography estimates
  - perfect for camera rotation or planar scene content
  - but problematic for photos that are captured handheld
- need to explicitly handle parallax between images
  - e.g. Parallax-tolerant Image Stitching [Zhang & Liu, CVPR 2014]

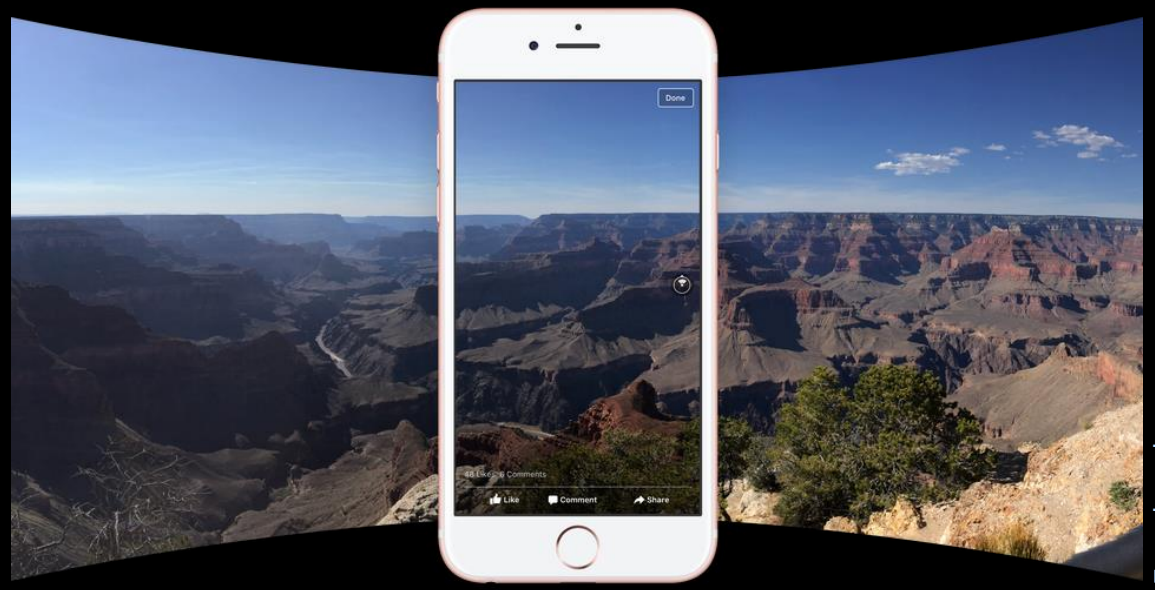


Brown & Lowe 2007

Zhang & Liu 2014

Applications

- now built into all mobile phones
- one simple camera sweep
- panorama computed on the fly

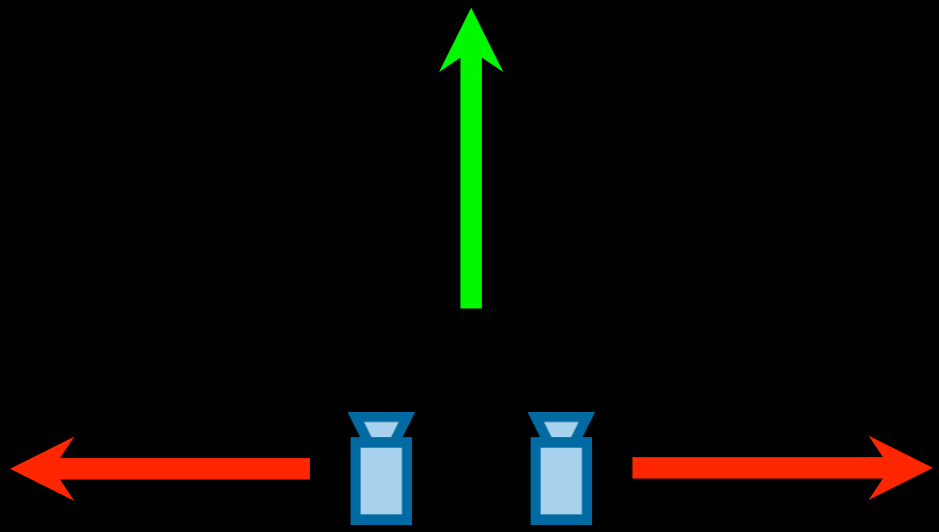


Facebook

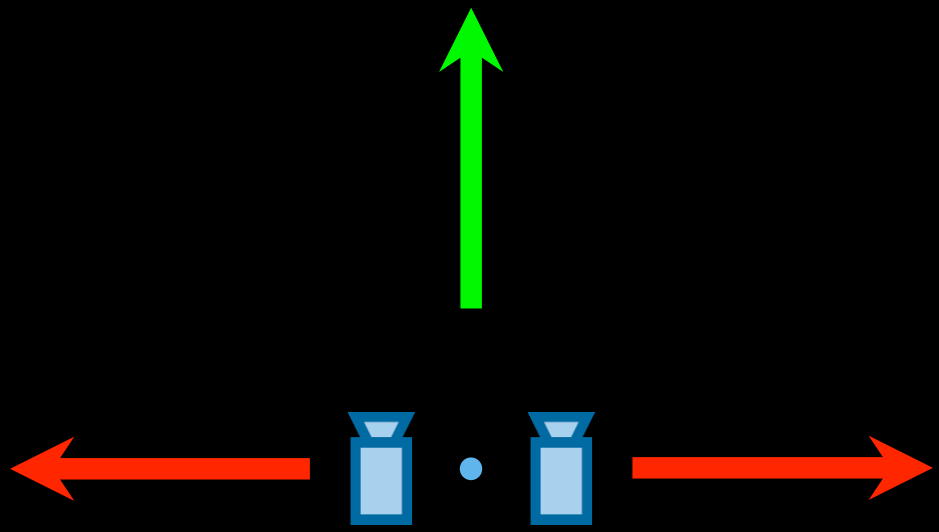
- consumer 360° cameras
- stitch views of two 180°+ fisheye cameras
- capturing photos and videos

Ben Claremont

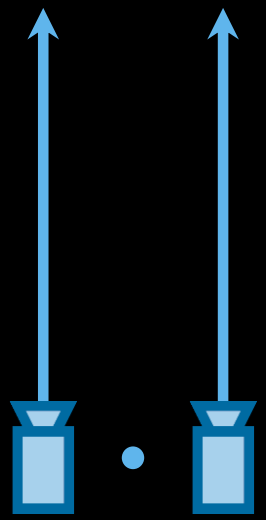
Capturing stereo panoramas



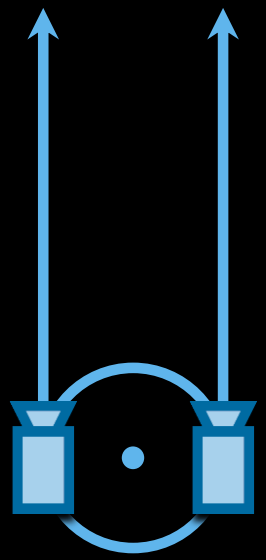
Capturing stereo panoramas



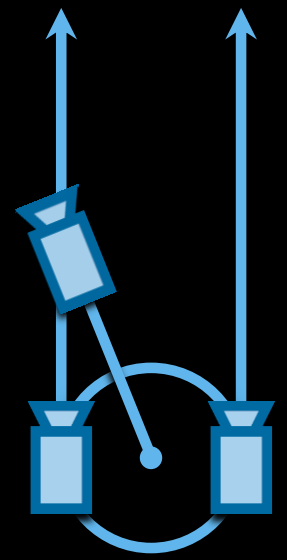
Capturing stereo panoramas



Capturing stereo panoramas

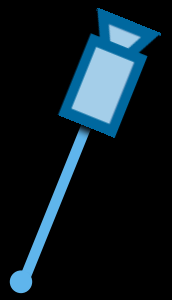


Capturing stereo panoramas



Omnistereo: Panoramic Stereo Imaging
Peleg et al., *IEEE TPAMI 2001*

Capturing stereo panoramas



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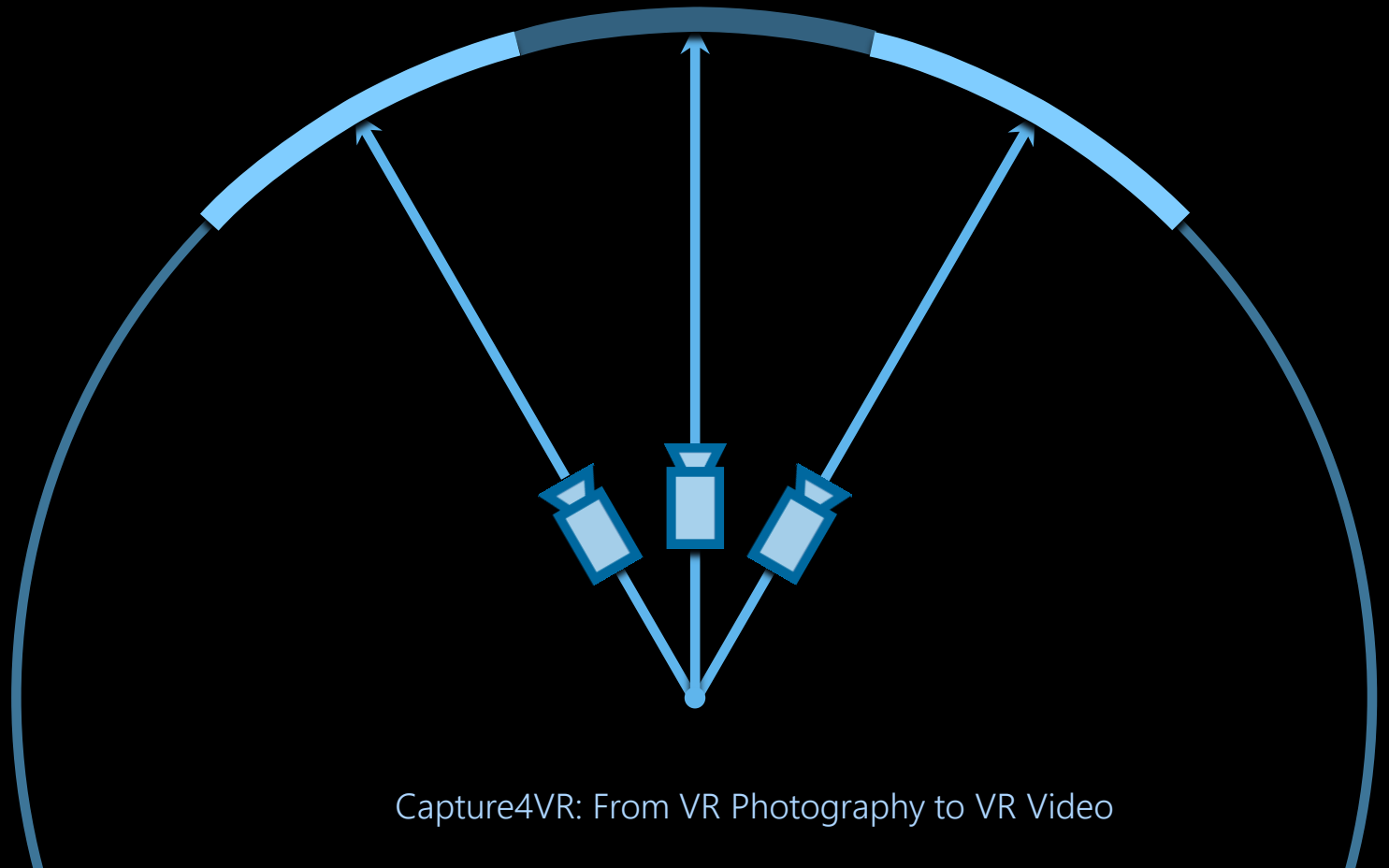
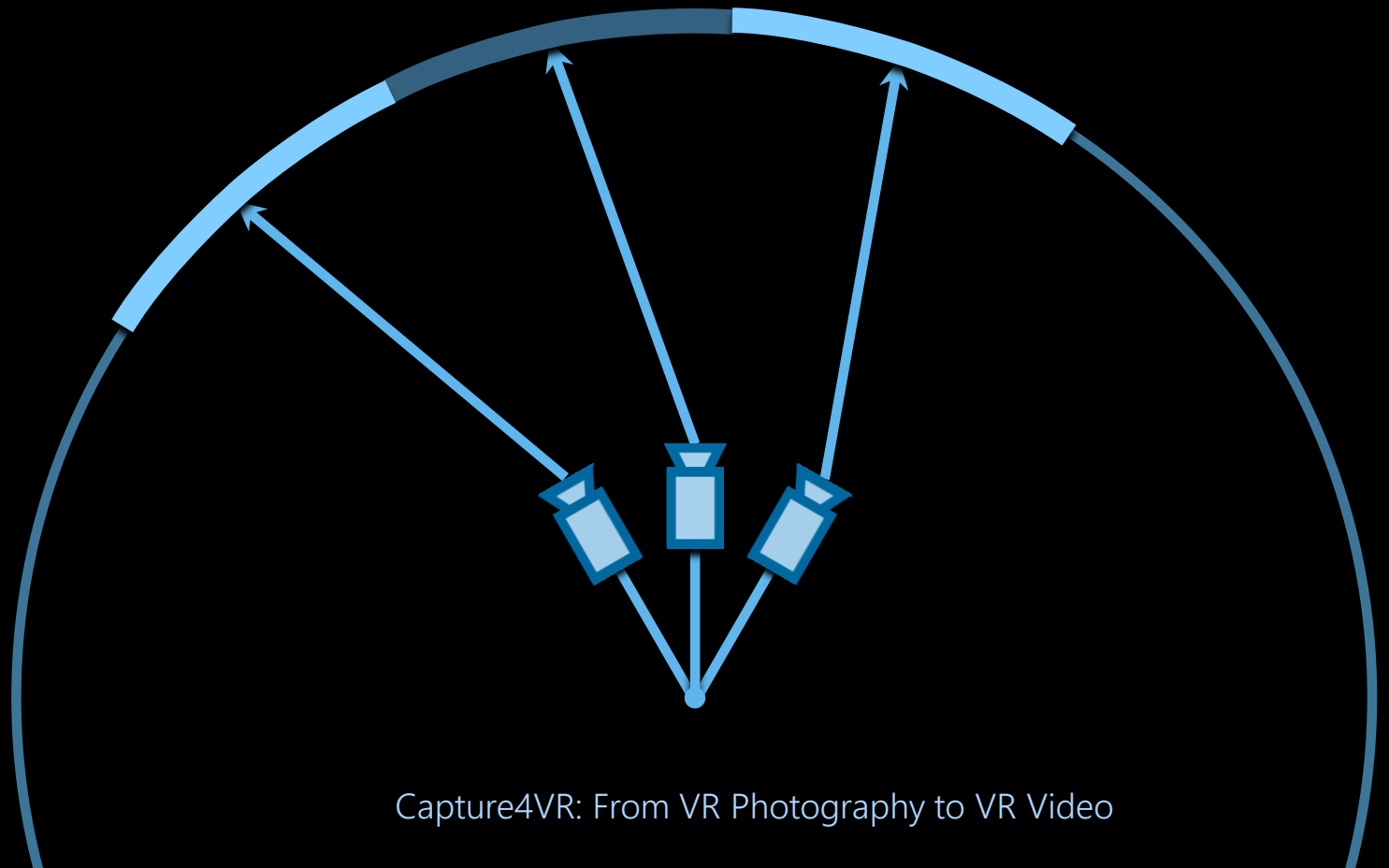
Capturing stereo panoramas



Capturing stereo panoramas



Capturing stereo panoramas

Input video:

Capturing stereo panoramas

Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*

Image alignment

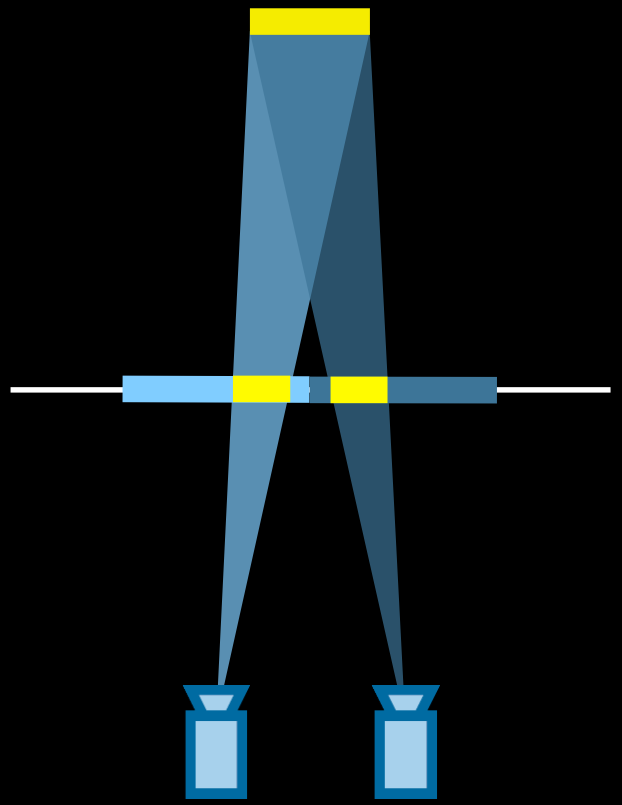
image-based alignment

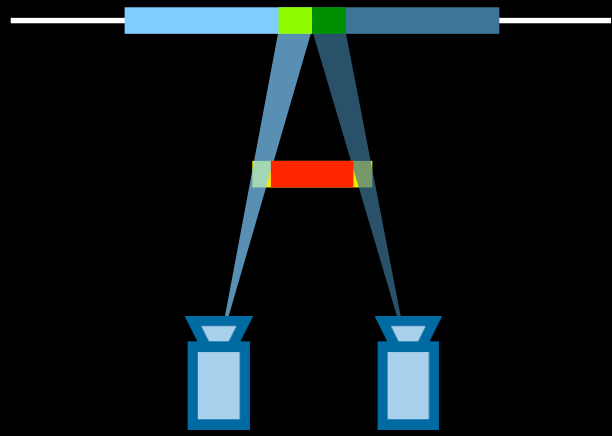
SfM-based alignment

Strip blending artefacts

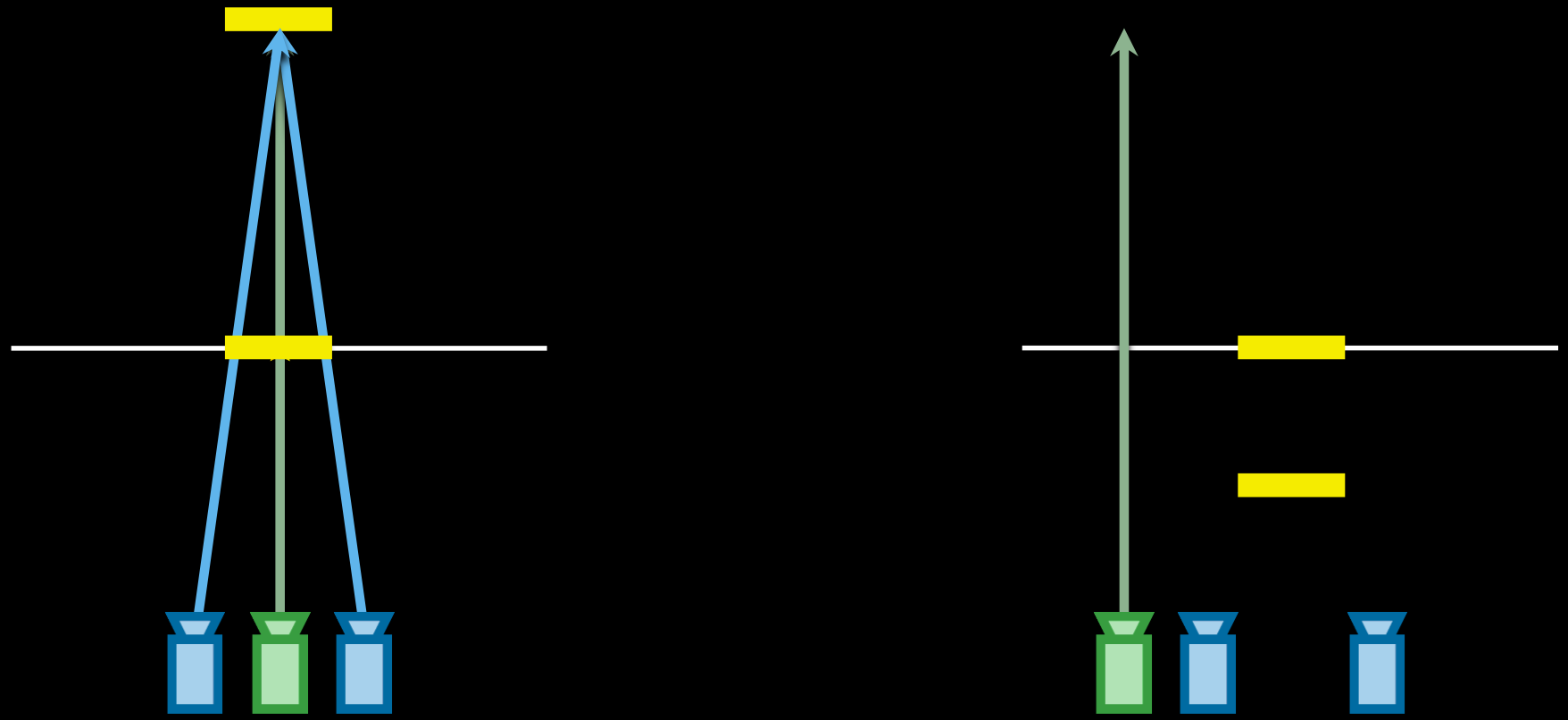
© dataset 'refaim' by Rav-Acha et al., IJCV 2008

Duplication + truncation





Flow-based ray interpolation



Strip blending artefacts

© dataset 'refaim' by Rav-Acha et al., IJCV 2008

Flow-based blending

Blending comparison

No blending

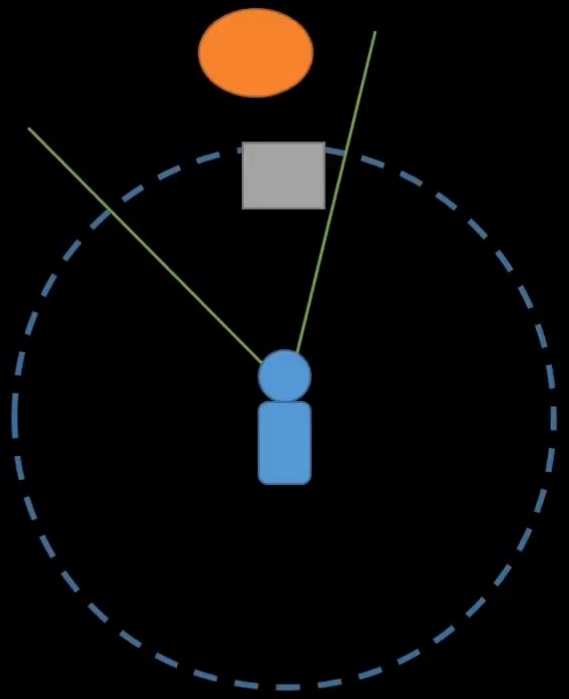
Flow-based blending

Stereo 3D panorama

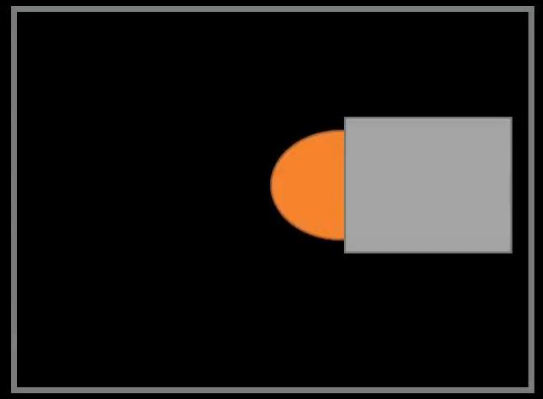
Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*


360 °
zoom
Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*
©2013 Richardt et al.

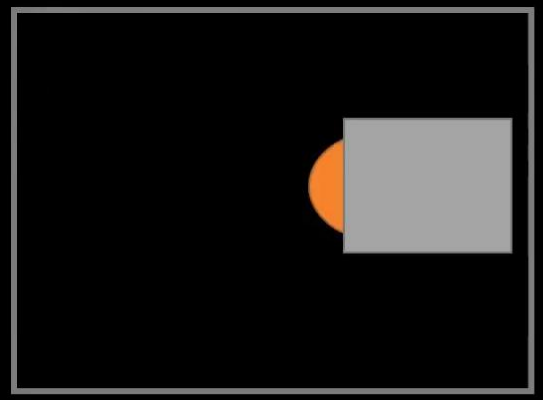
Motion parallax



Top View of the Scene



Head-Motion Parallax

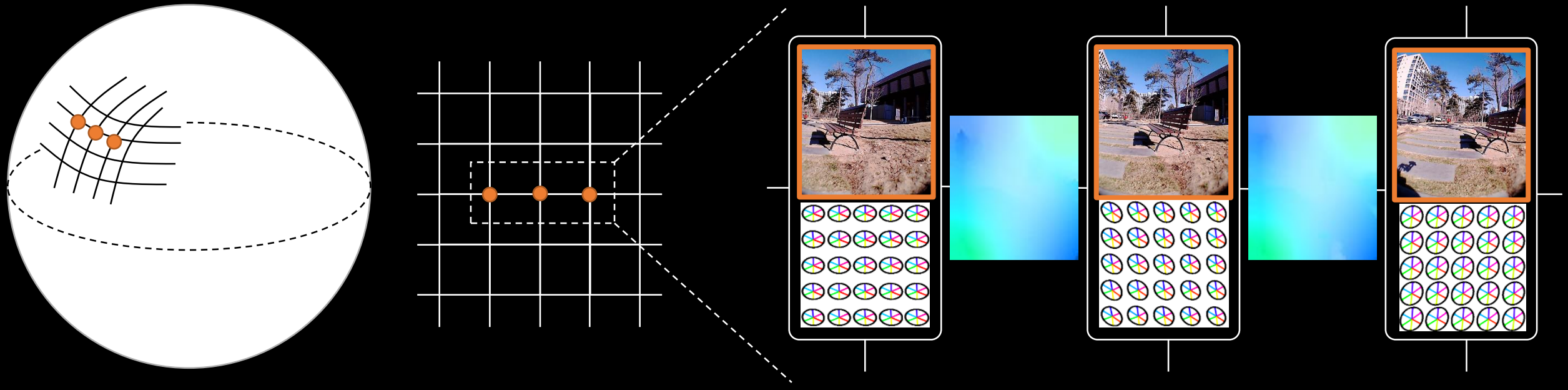


No Head-Motion Parallax

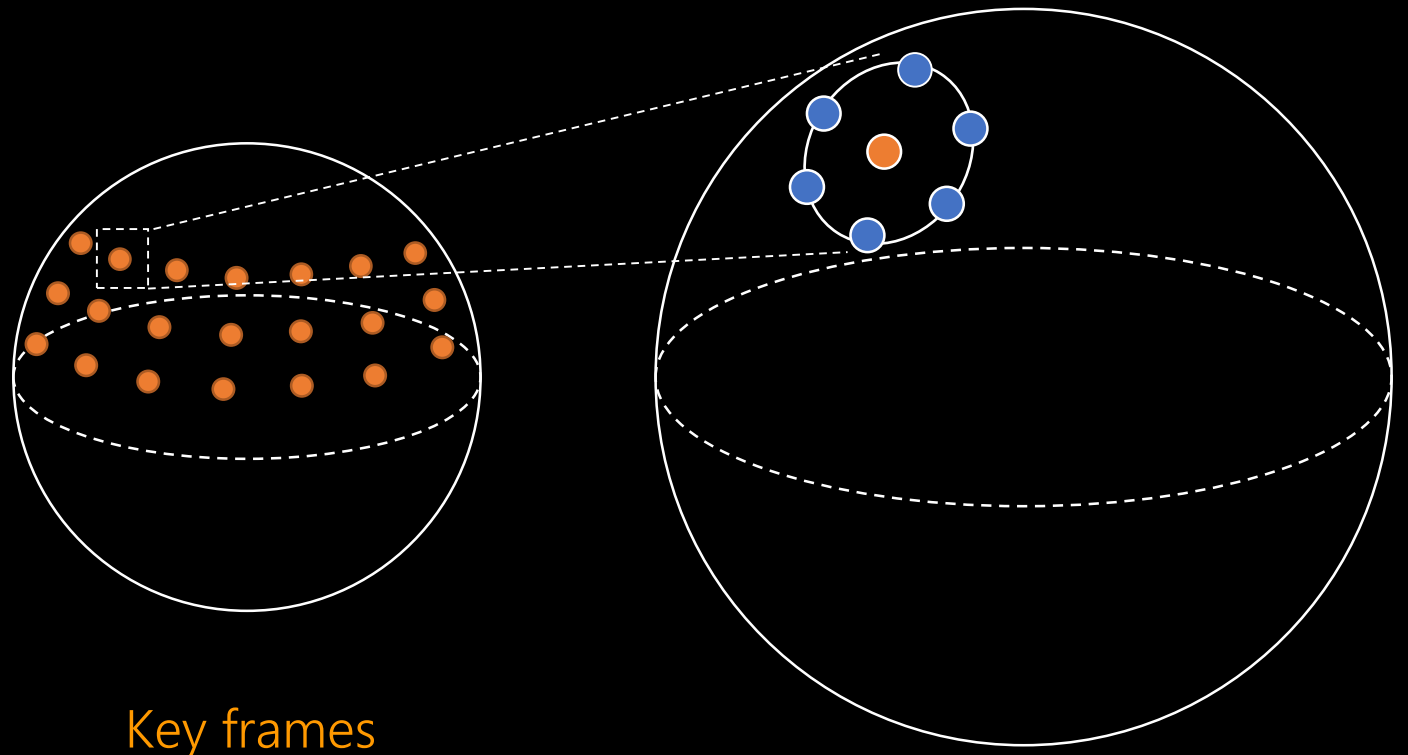
Luo et al., TVCG 2018

Parallax360: Scene representation

- **Key frames:** colour information of the scene
- **Disparity motion fields:** implicit 3D information at each key frame
- **Pairwise motion fields:** efficient and smooth viewpoint transitions in novel-view synthesis

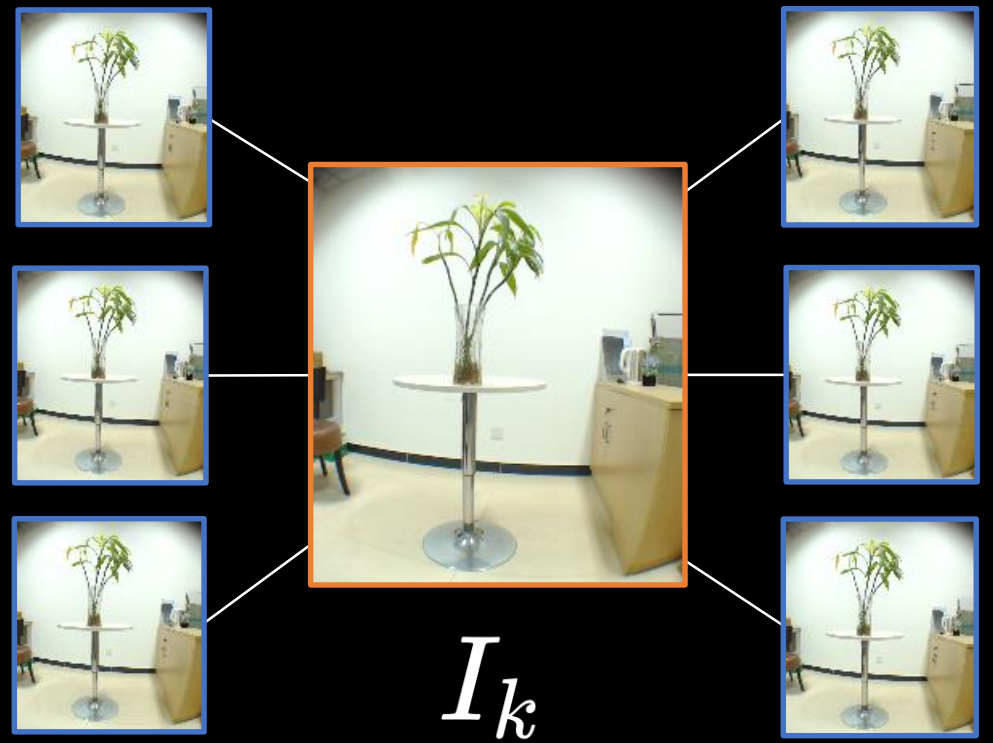


Parallax360: Image capture scheme



Key frames

Relative frames

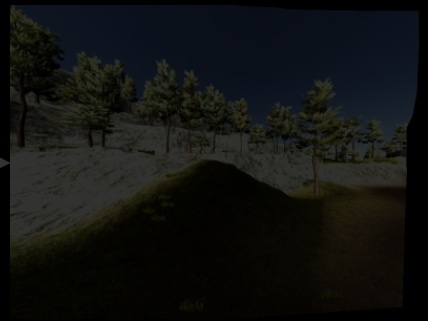


I_k

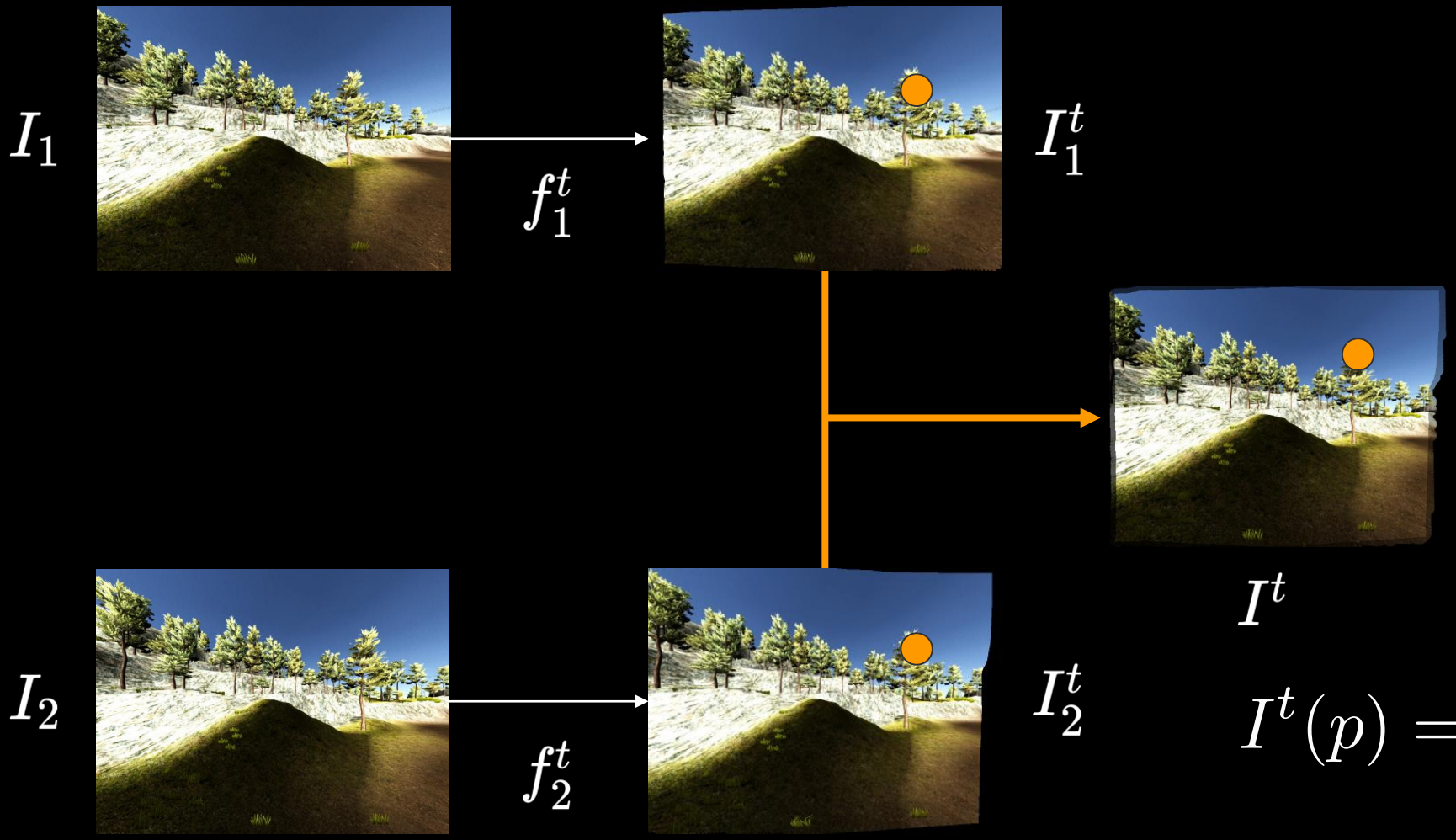
Parallax360: Novel-view synthesis

I_1  f_1^t  I_1^t

$$I_1^t(p) = I_1\left((f_1^t)^{-1}(p)\right)$$

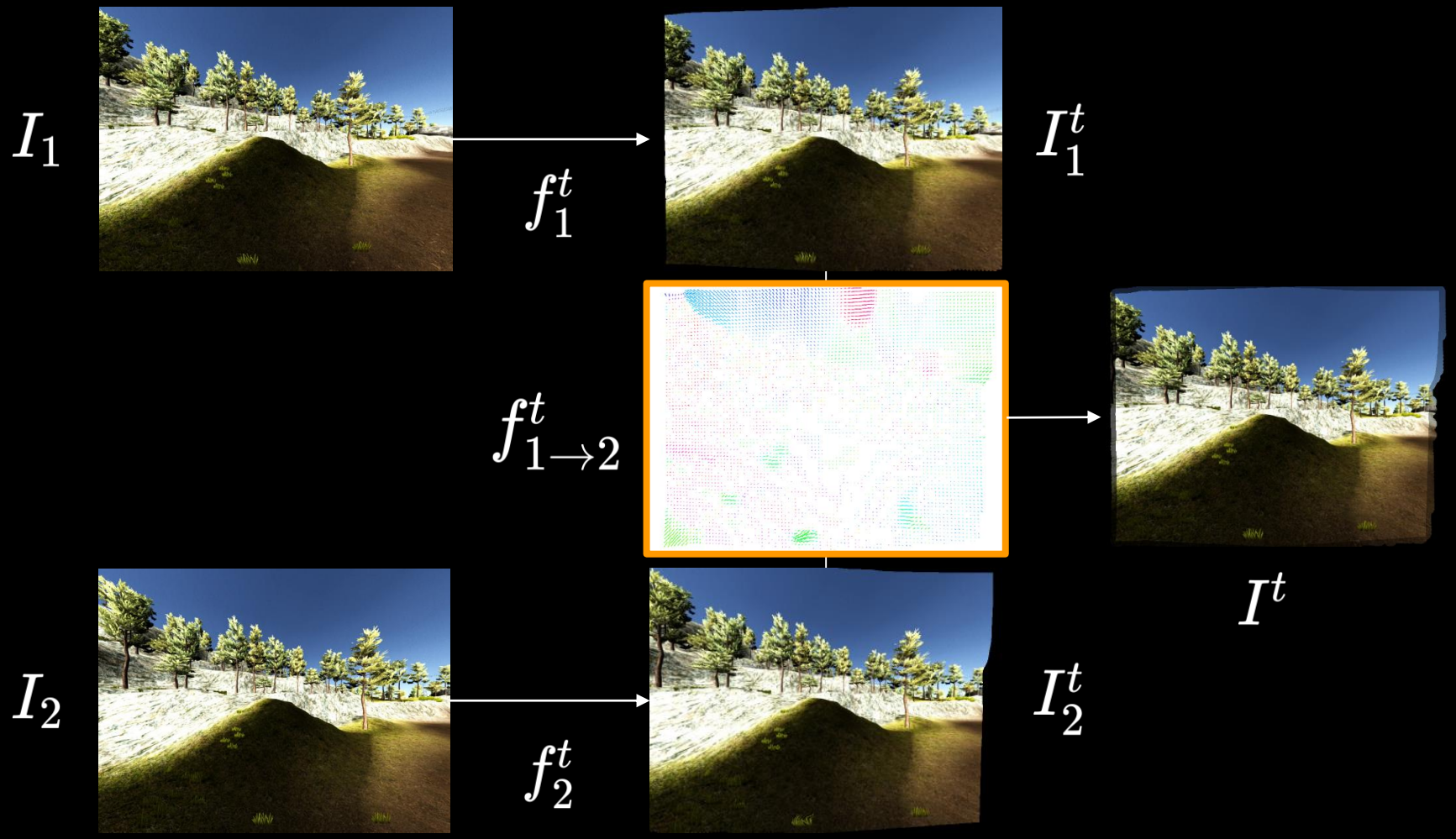
I_2  f_2^t  I_2^t

Parallax360: Novel-view synthesis



$$I^t(p) = \sum_{k=1}^{K} \overline{w}_k I_k^t(p_k)$$

Parallax360: Novel-view synthesis



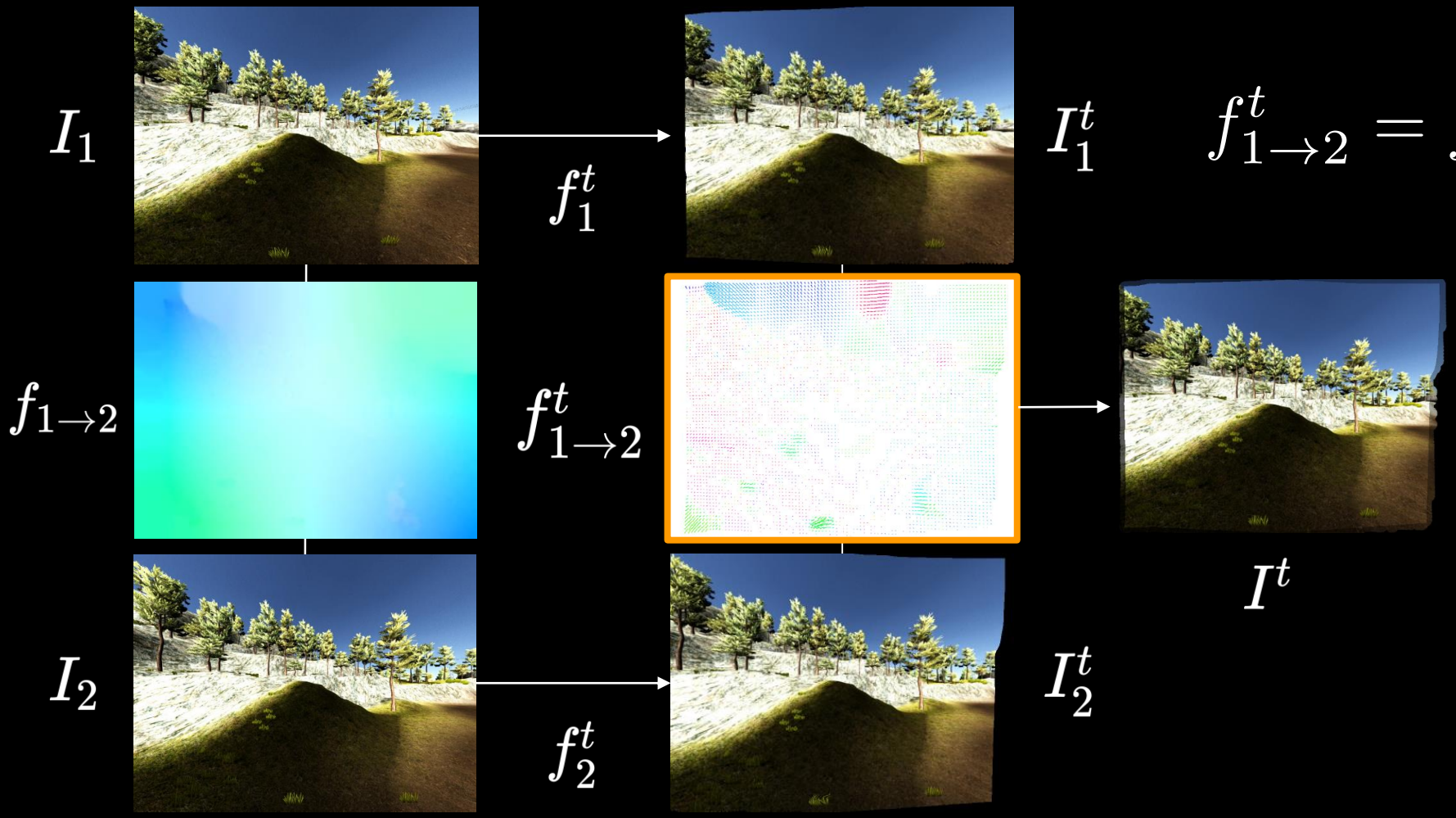
Experiments and Results

Evaluation of view synthesis quality:

Flow-Based Blending

Alpha Blending

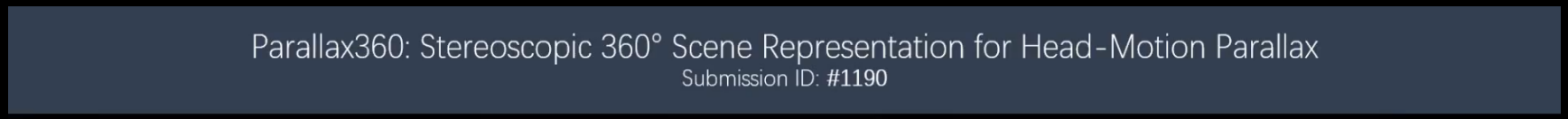
Parallax360: Novel-view synthesis



$$f_{1\to 2}^t = f_2^t \circ f_{1\to 2} \circ (f_1^t)^{-1}$$

Parallax360: Results

Comparison on real-world scenes:

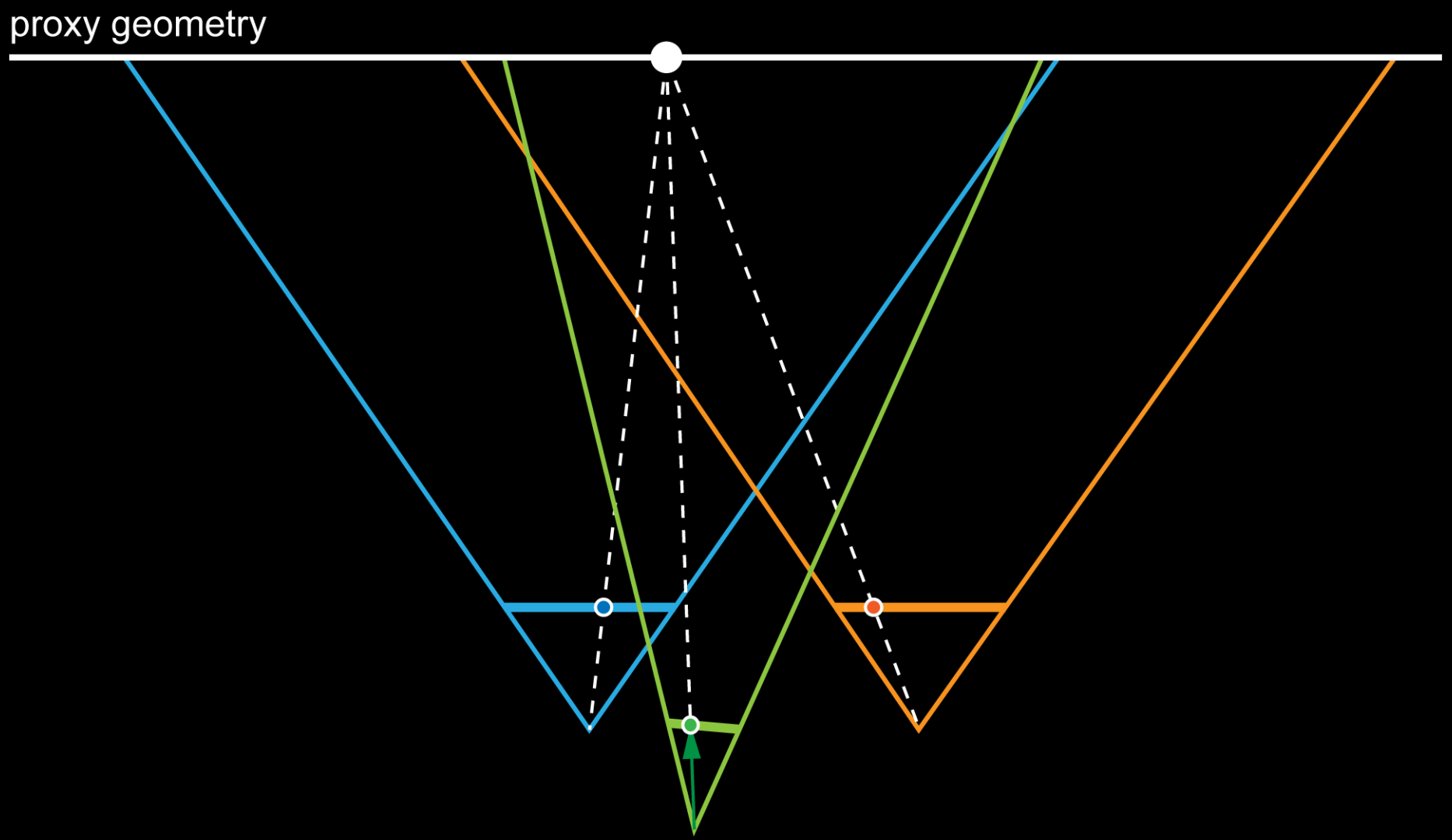


Stereo Panorama

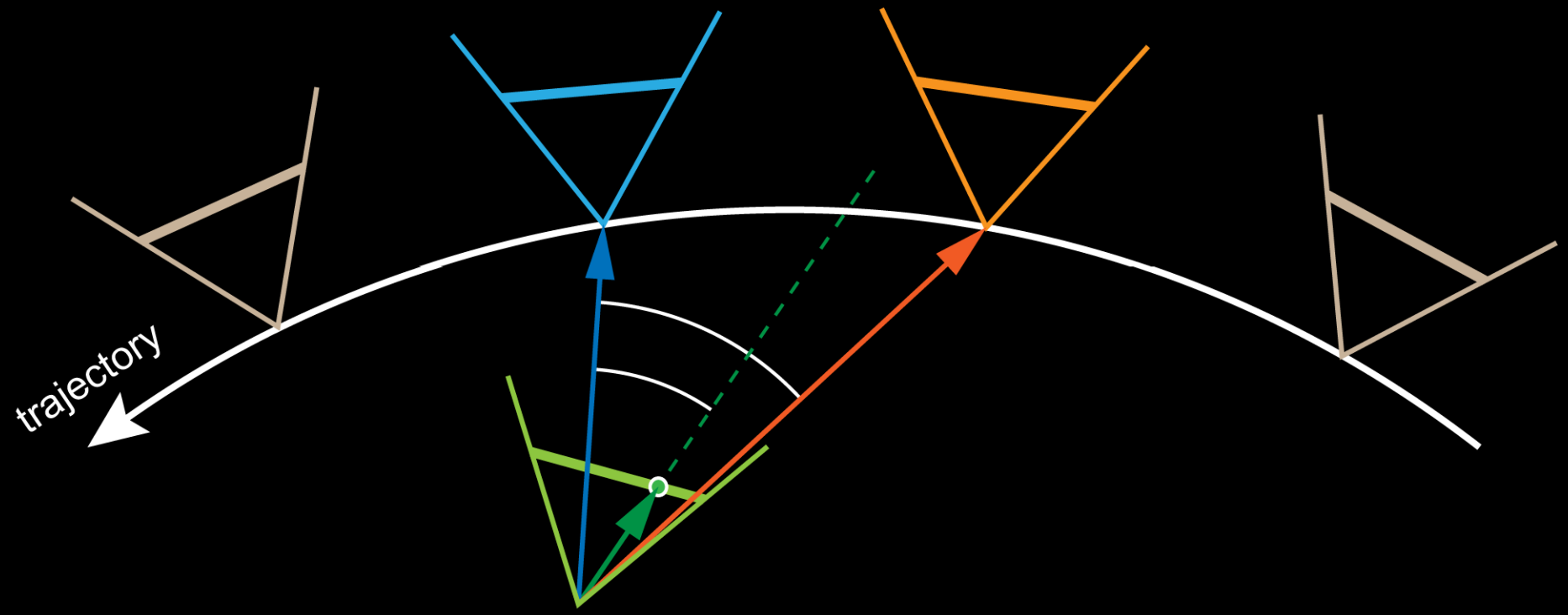
Input video

Dataset:	Rooftop
Capture:	rig
Resolution:	960×1280
Field of view:	88°×104°
Images:	360
Radius:	1.22 m

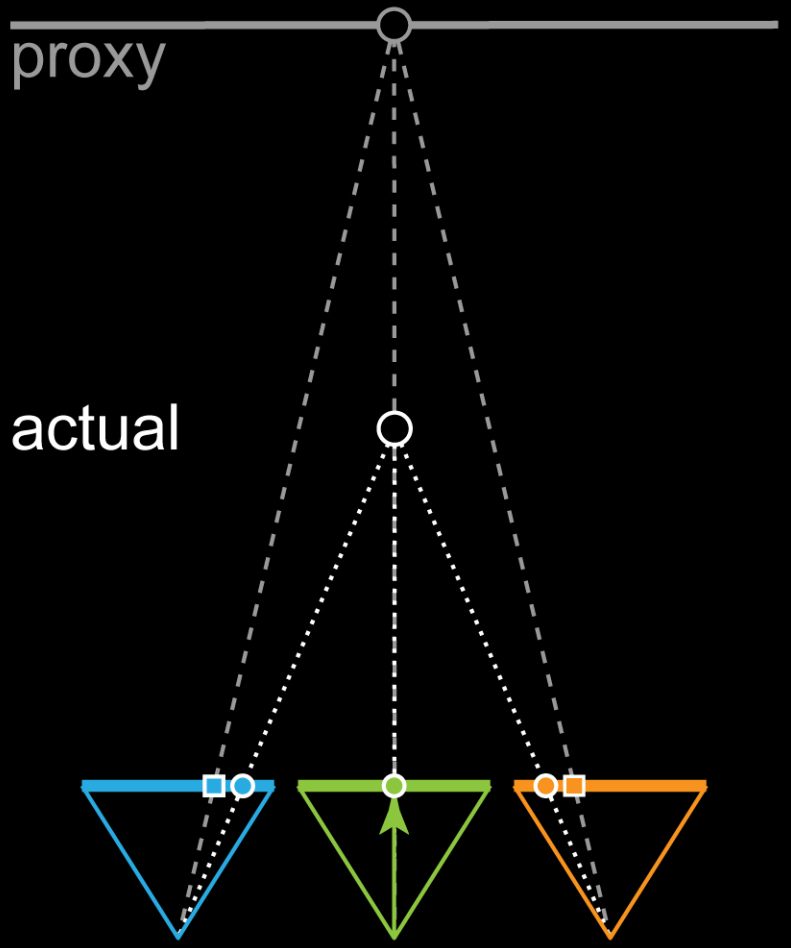
MegaParallax: Proxy-based novel-view synthesis



MegaParallax: Per-ray novel-view synthesis



MegaParallax: Flow-based blending



MegaParallax: Forward–backward motion

Parallax360 view synthesis
[Luo et al., 2018] (constant perspective)

MegaParallax
[Bertel et al., 2019] (with changing perspective)

Bertel et al., MegaParallax, TVCG 2019

MegaParallax: Input video

Bertel et al., MegaParallax, TVCG 2019

MegaParallax: result

Bertel et al., MegaParallax, TVCG 2019

MegaParallax: Lateral translation

Megastereo
[Richardt et al., 2013]

Parallax360
[Luo et al., 2018]

MegaParallax
[Bertel et al., 2019]

Bertel et al., MegaParallax, TVCG 2019

Panoramas summary

- Panoramas:
  - widespread adoption in smartphones + 360 cameras
  - but flat appearance due to lack of depth
- Stereo panoramas:
  - appearance of depth in all directions
  - extended to stereo 360 video [Anderson et al. 2016, Schroers et al. 2018]
  - but no support for head translation (or depth at poles)
- Motion parallax:
  - additional degrees of freedom allow more immersive exploration

Next up

Start	Topic	Speaker
14:00	1. Introduction	Christian Richardt, Bath
14:20	2. 360° (Stereo) Panoramas	Christian Richardt, Bath
14:40	3. 3D Photography	Peter Hedman, UCL
15:00	4. Light Field Photography	Ryan S. Overbeck
15:20	Q&A + *Break*	
15:35	5. 360 and ODS Video	Brian Cabral, Facebook
15:55	6. Live ODS Video	Robert Konrad, Stanford
16:15	7. 6-DoF Video	Brian Cabral, Facebook
16:35	8. MR Capture Studios	Steve Sullivan, Microsoft
16:55	9. Conclusion + Q&A	All presenters