

Real-Time 3D Reconstruction and 6-DoF Tracking with an Event Camera

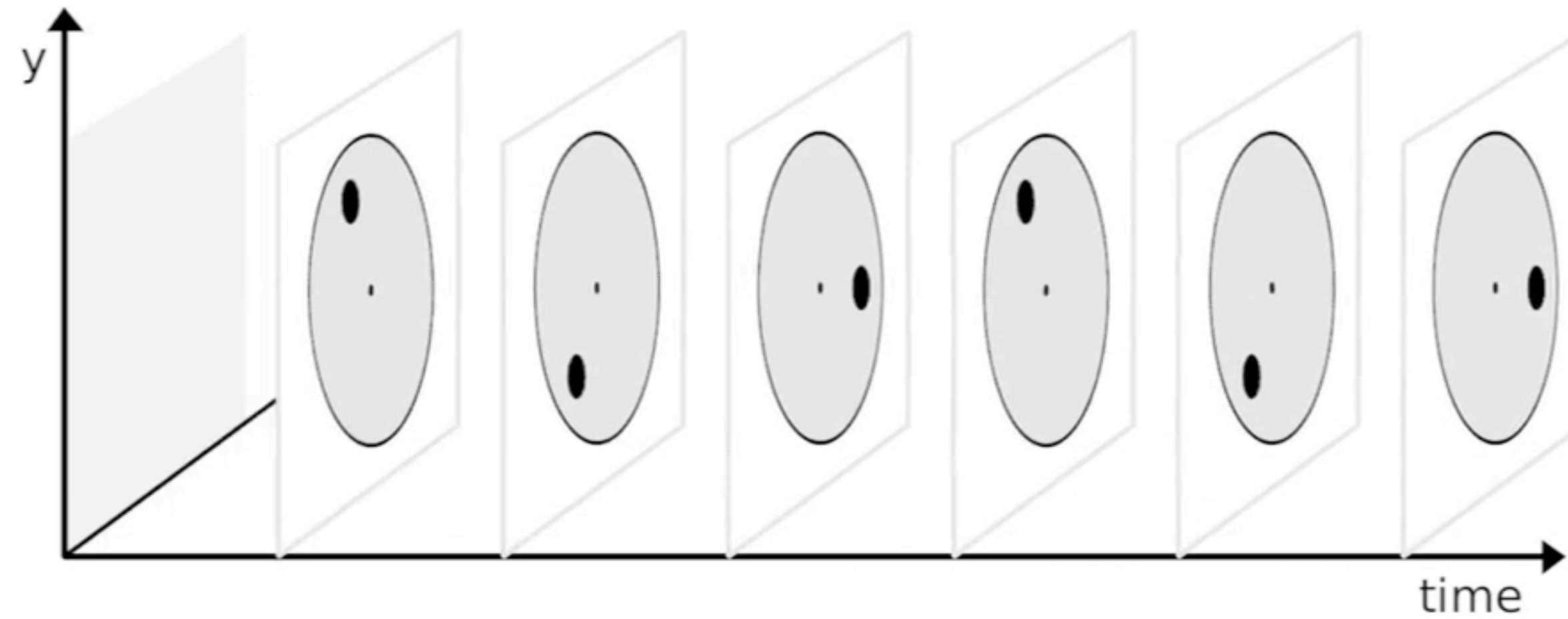
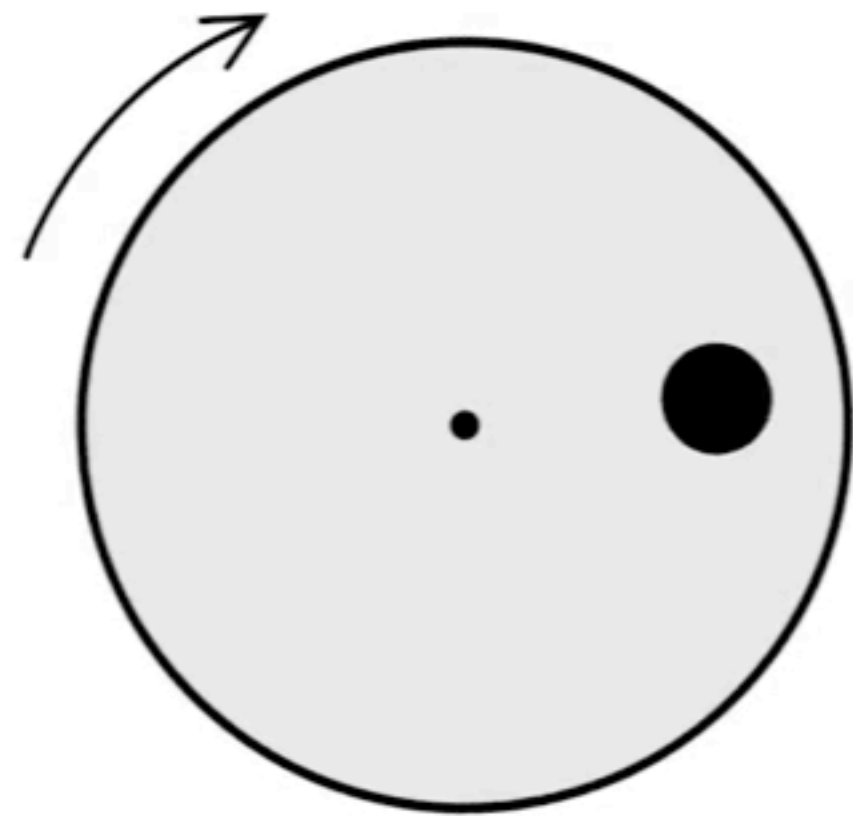
Hanme Kim, Stefan Leutenegger, and Andrew J. Davison

Robot Vision Group
Department of Computing
Imperial College London



Standard Camera vs Event Camera

Standard Camera



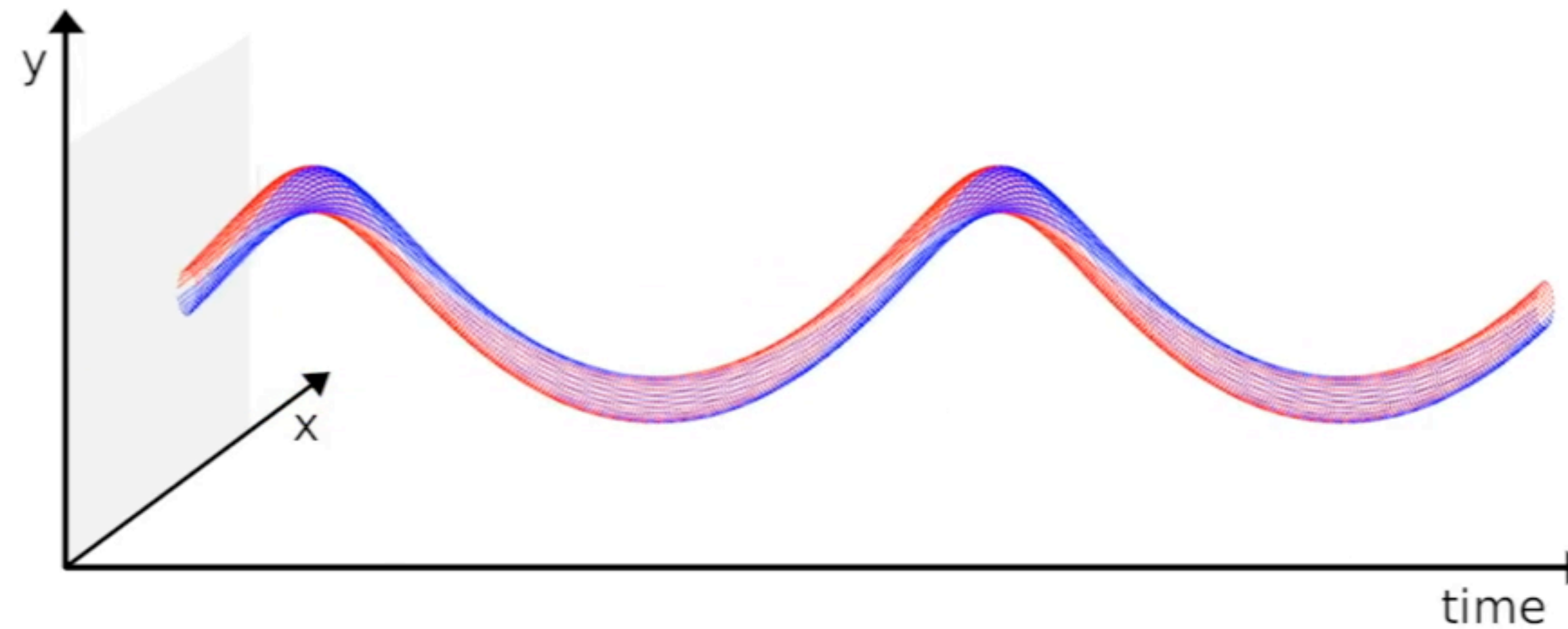
Standard Camera

✗ low frame rate

Event Camera

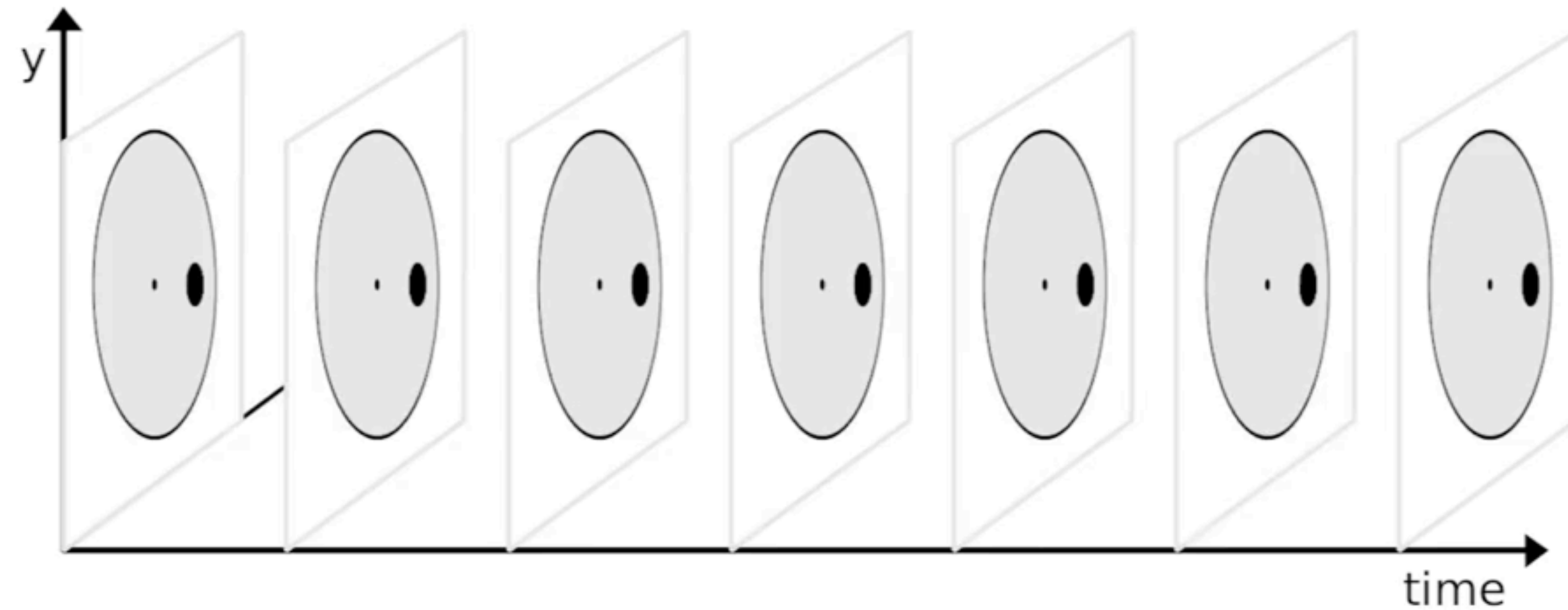
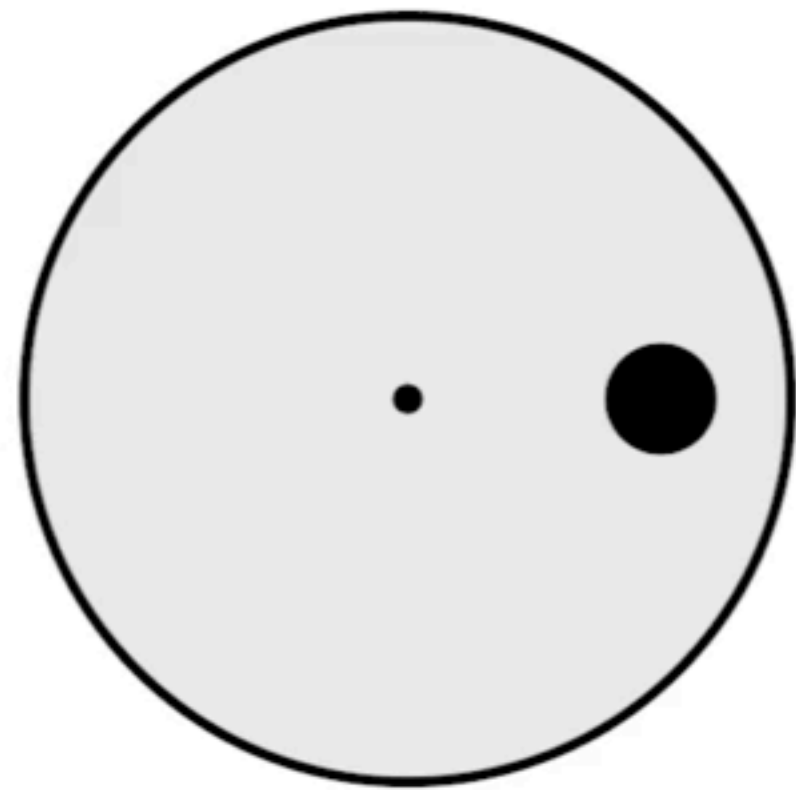
✓ high temporal resolution

Event Camera



Standard Camera vs Event Camera

Standard Camera



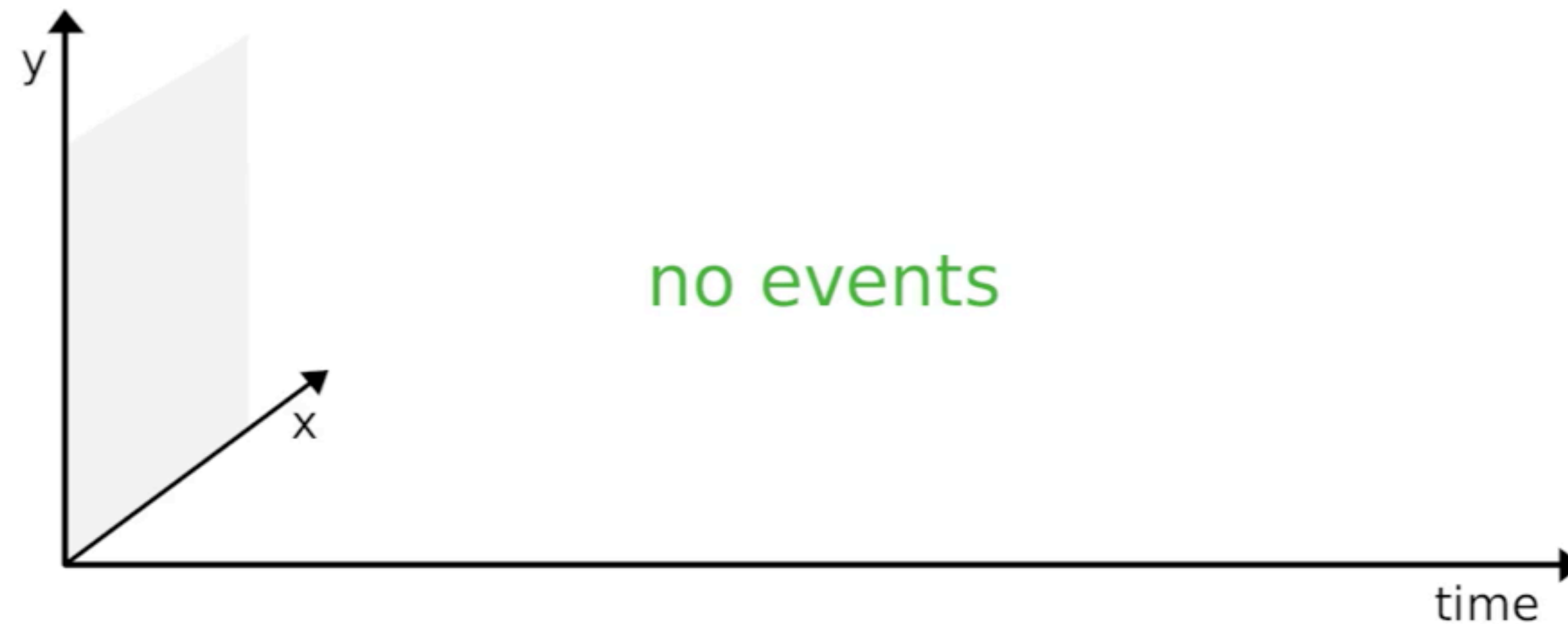
Standard Camera

- ✗ low frame rate
- ✗ redundant data
- ✗ high power consumption
- ✗ low dynamic range

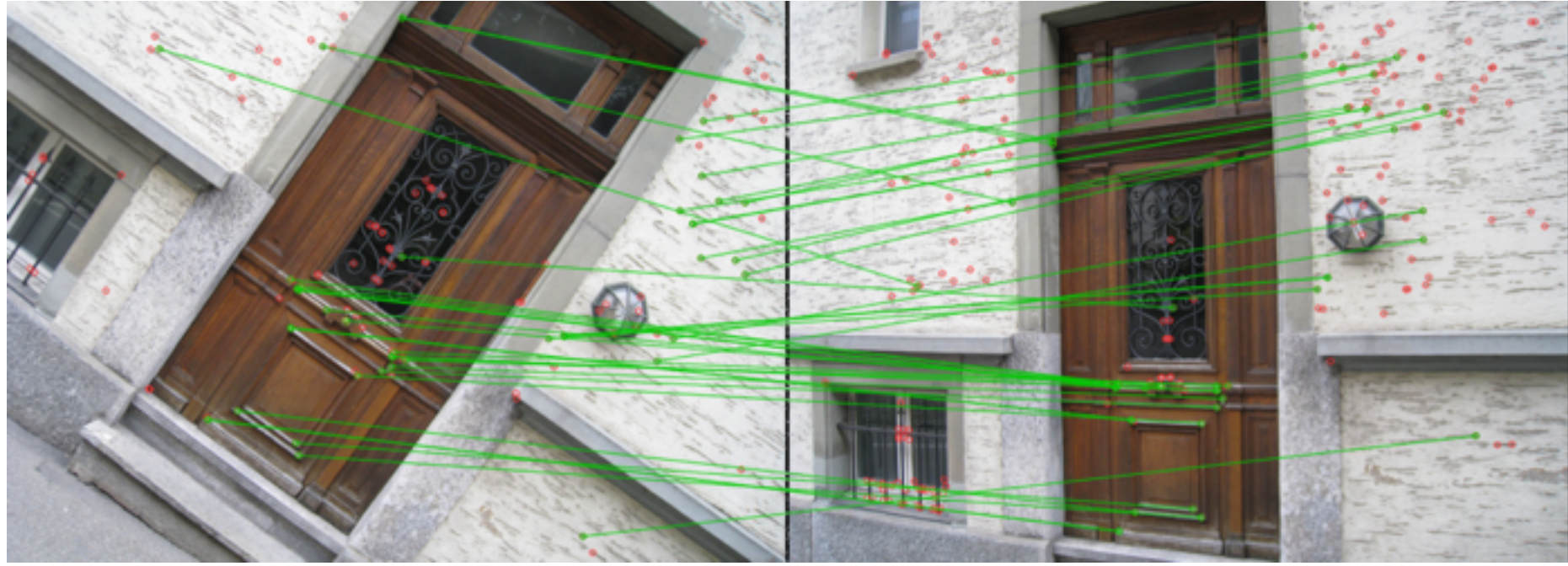
Event Camera

- ✓ high temporal resolution
- ✓ no redundant data
- ✓ low power consumption
- ✓ high dynamic range

Event Camera



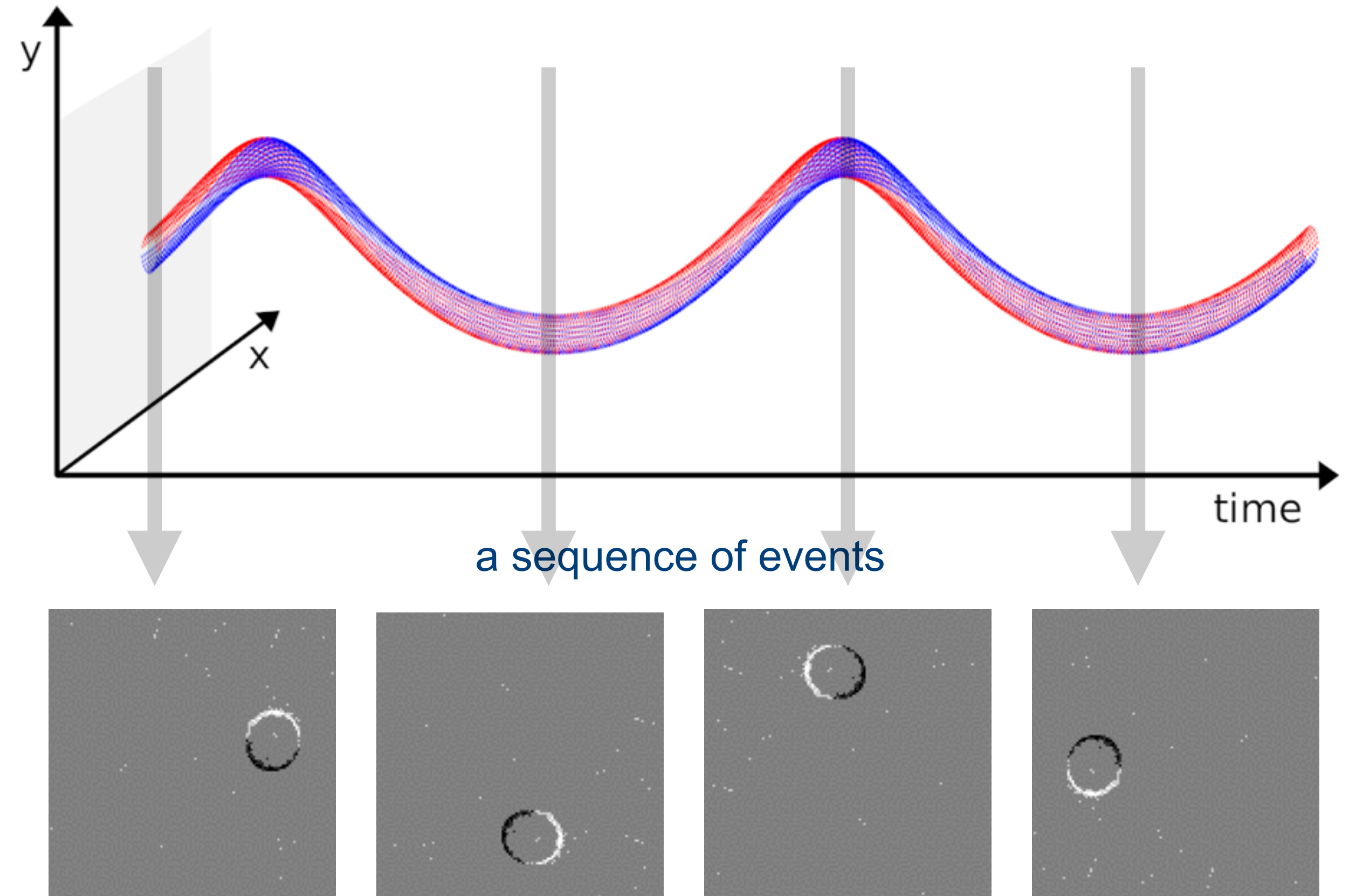
Can we use event cameras for SLAM problems?



feature detection & matching
[Leutenegger et al., ICCV'11]

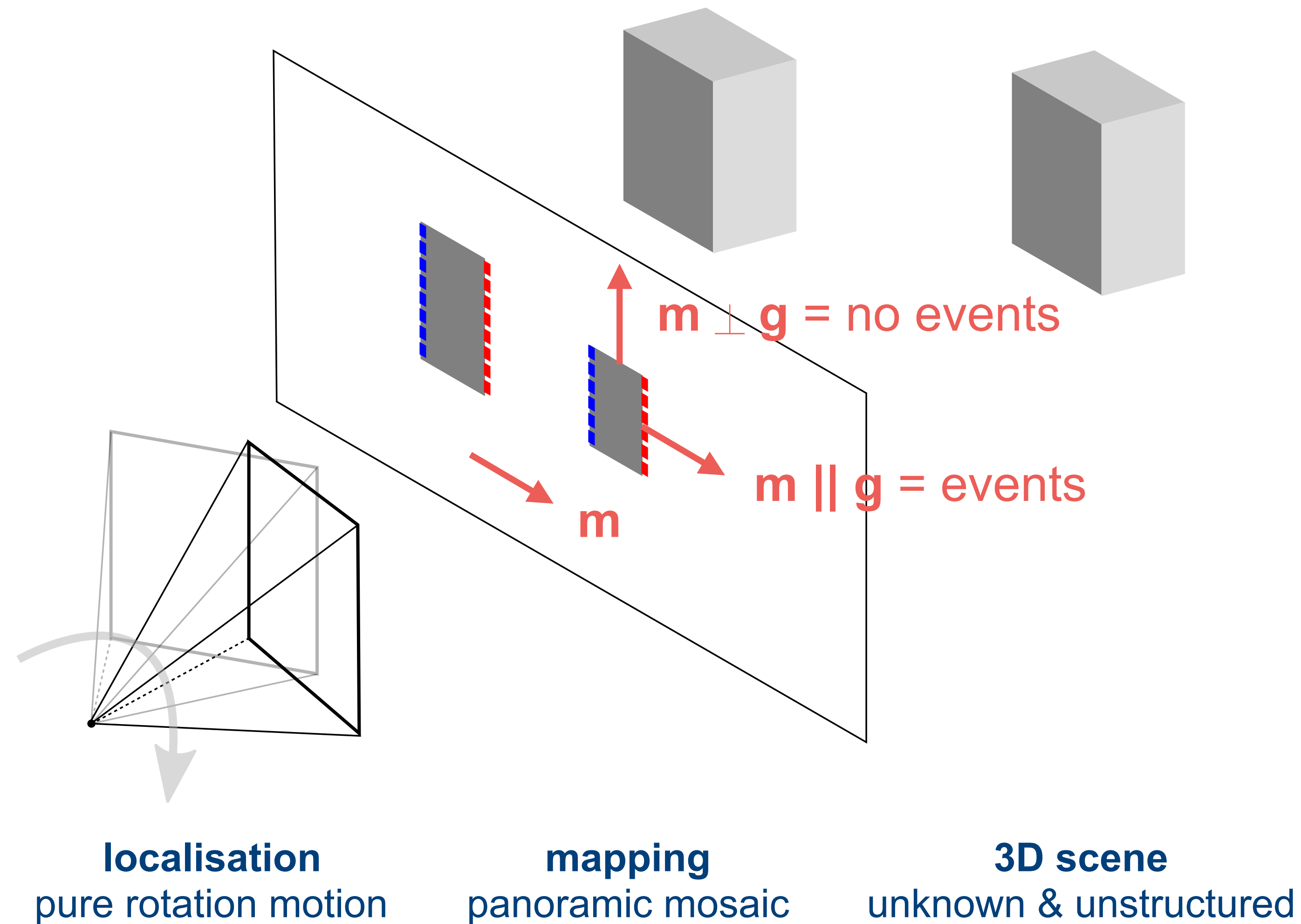


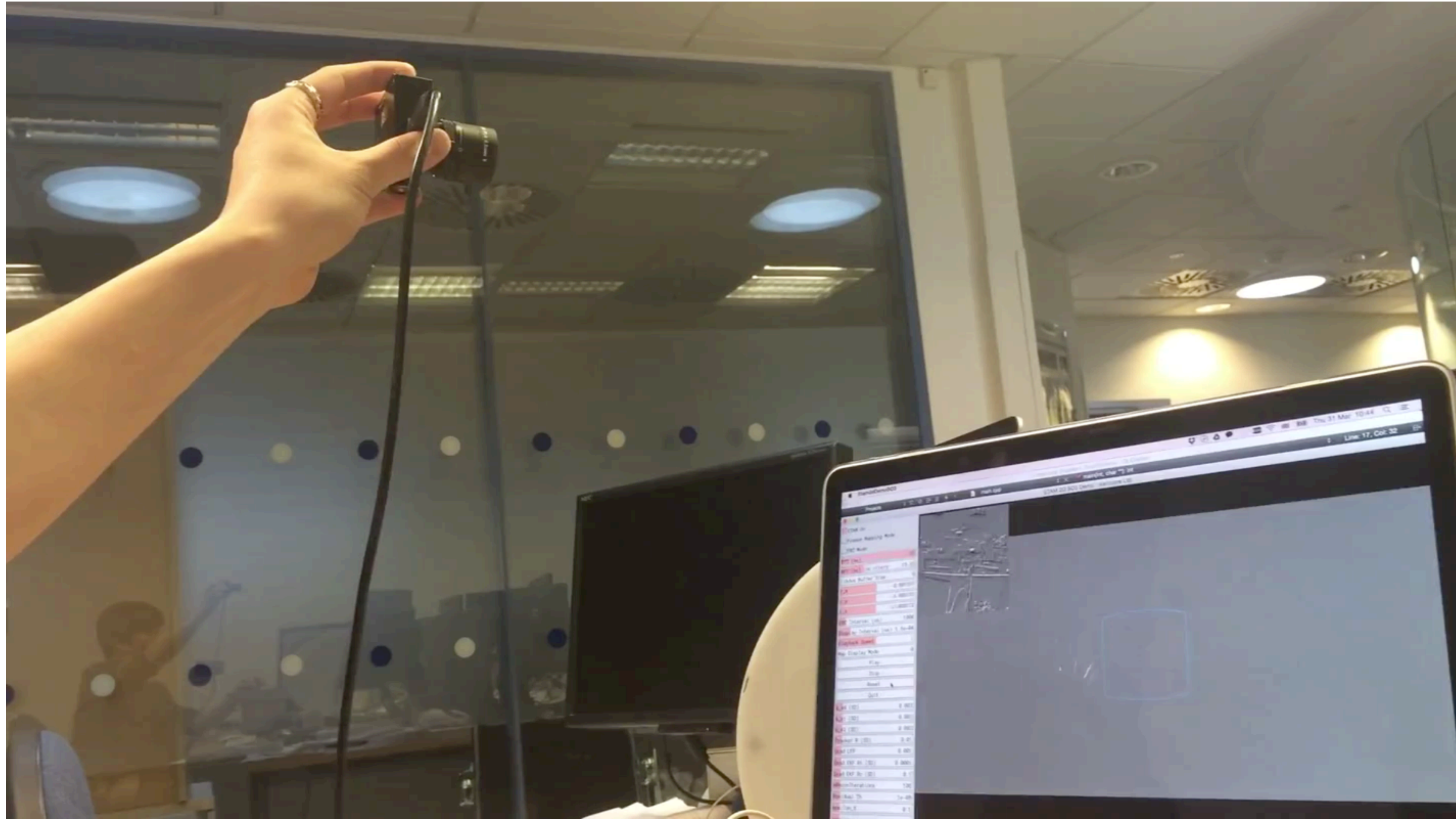
image alignment



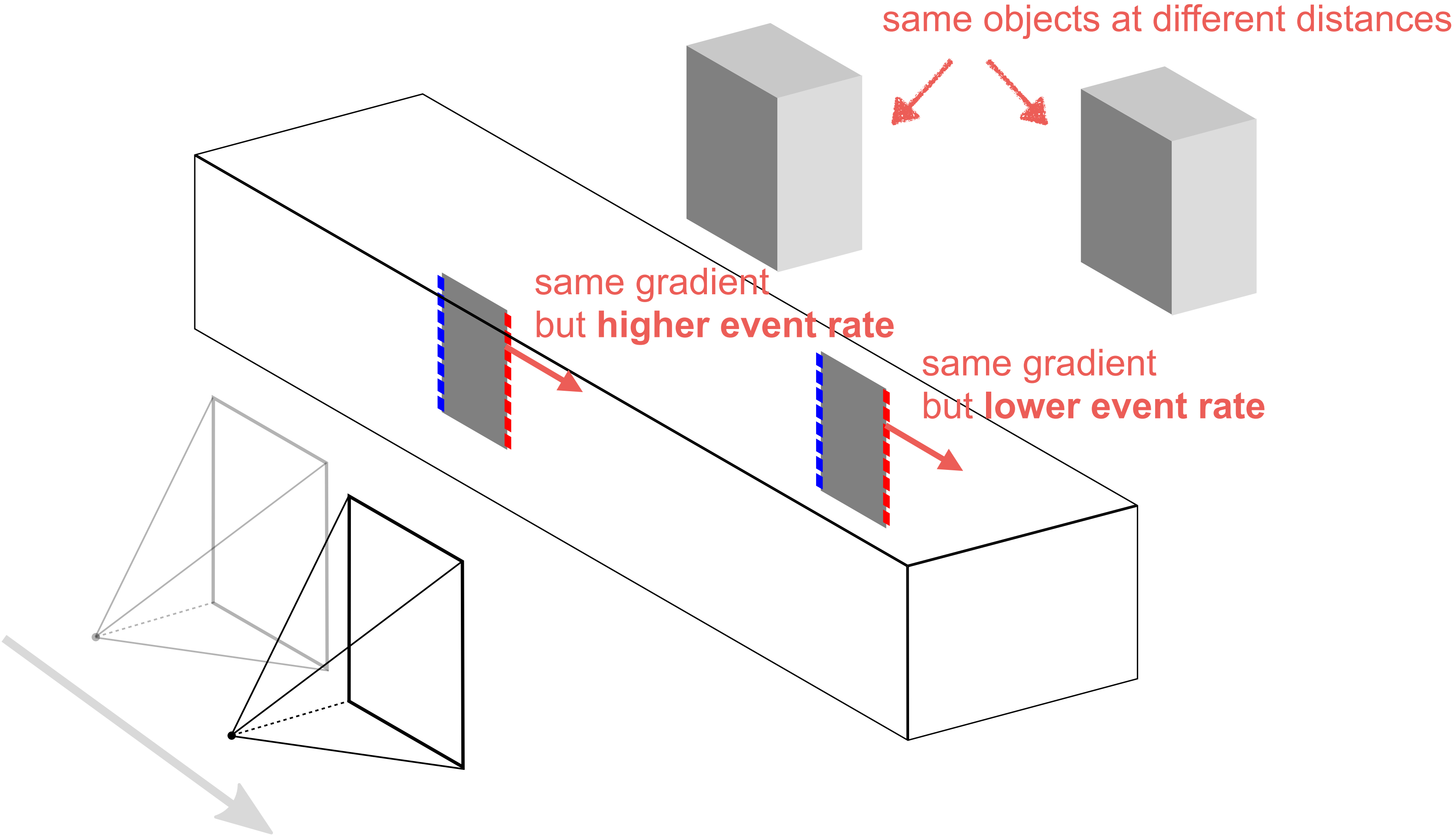
3-DoF Tracking and 2D Reconstruction

this has only been successful with restricted motion and 2D reconstruction [Kim et al., BMVC'14]





Towards 3D SLAM



localisation
6-DoF hand-held motion

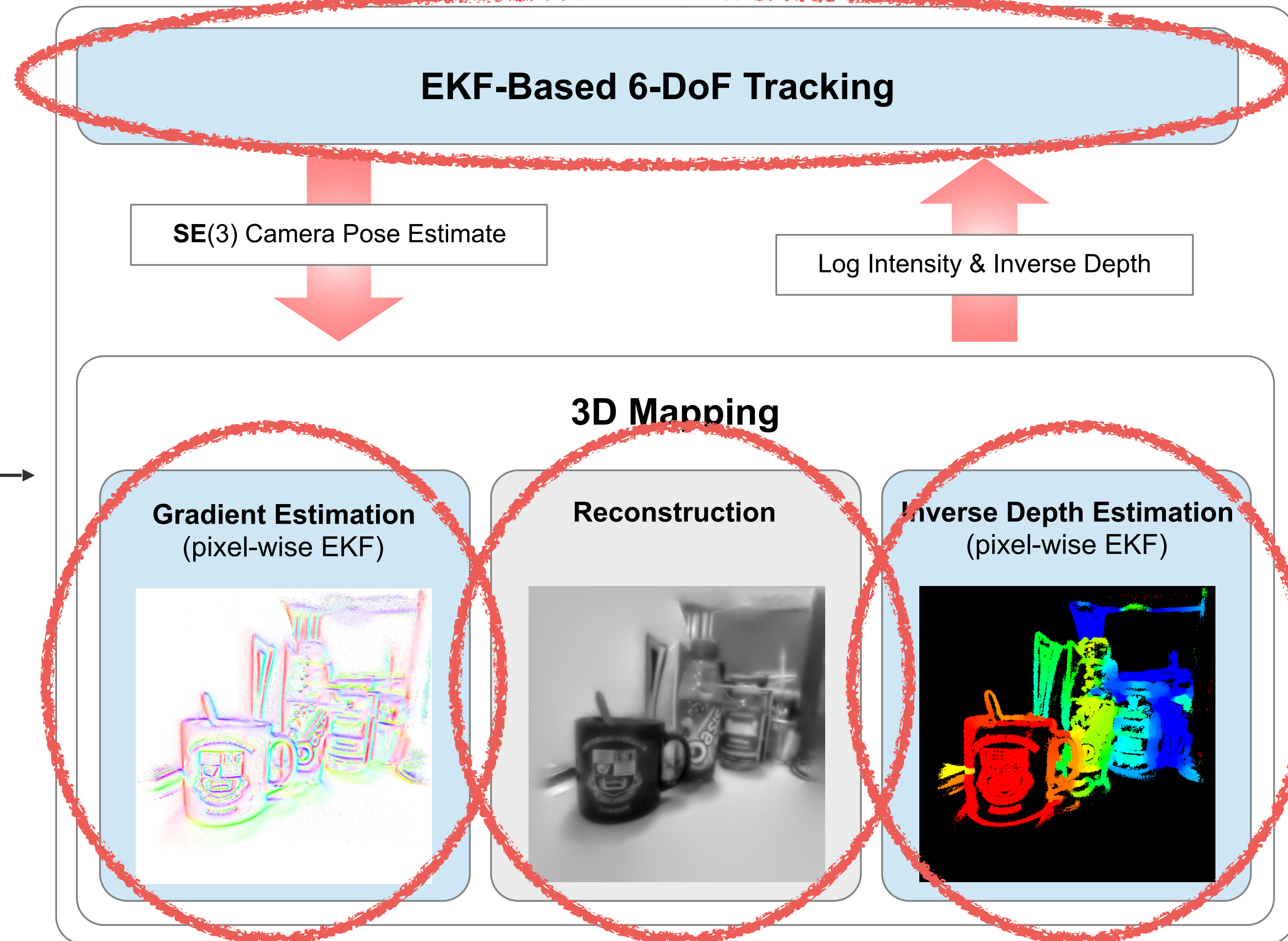
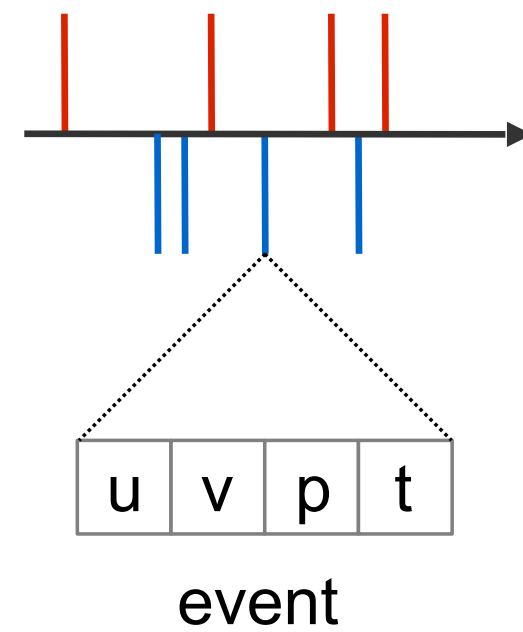
mapping
3D

3D scene
unknown & unstructured



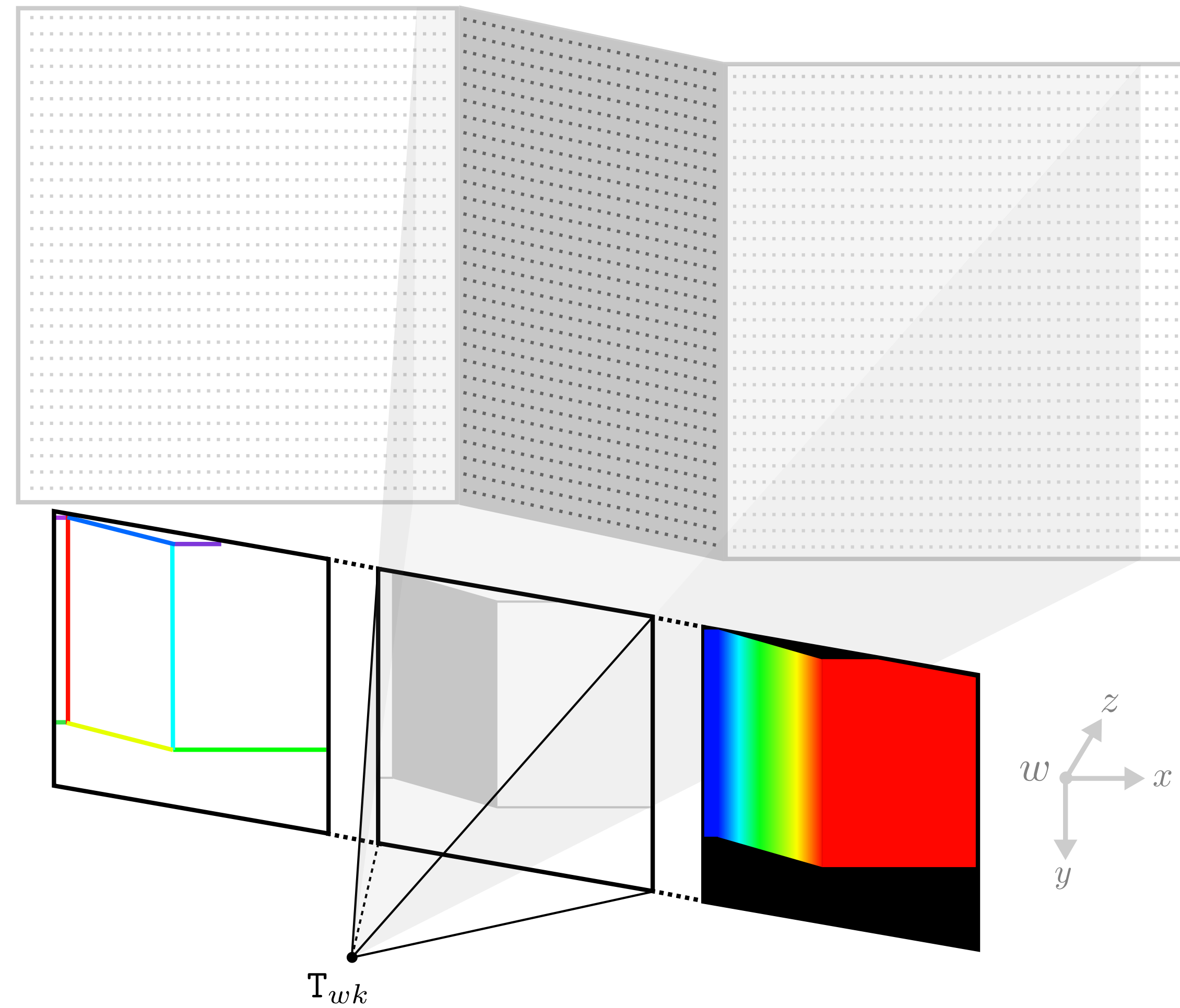
Method Overview

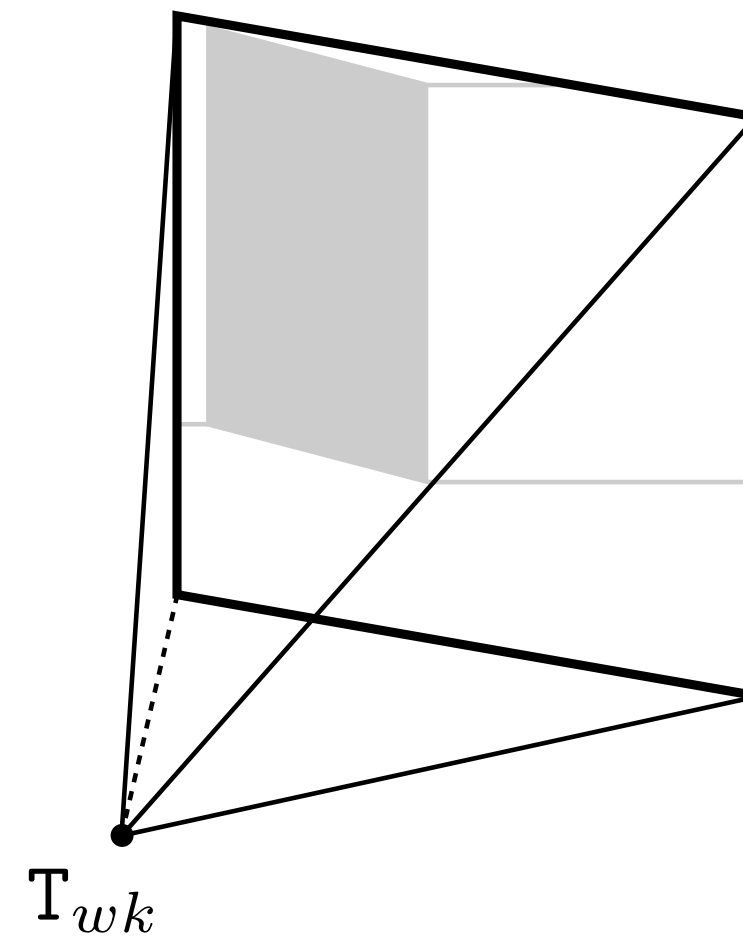
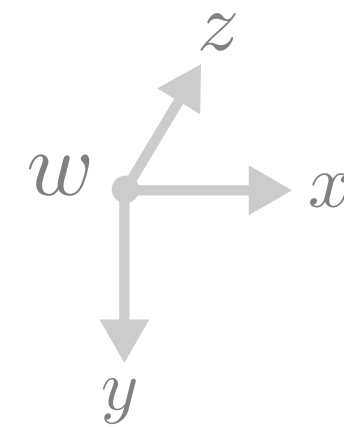
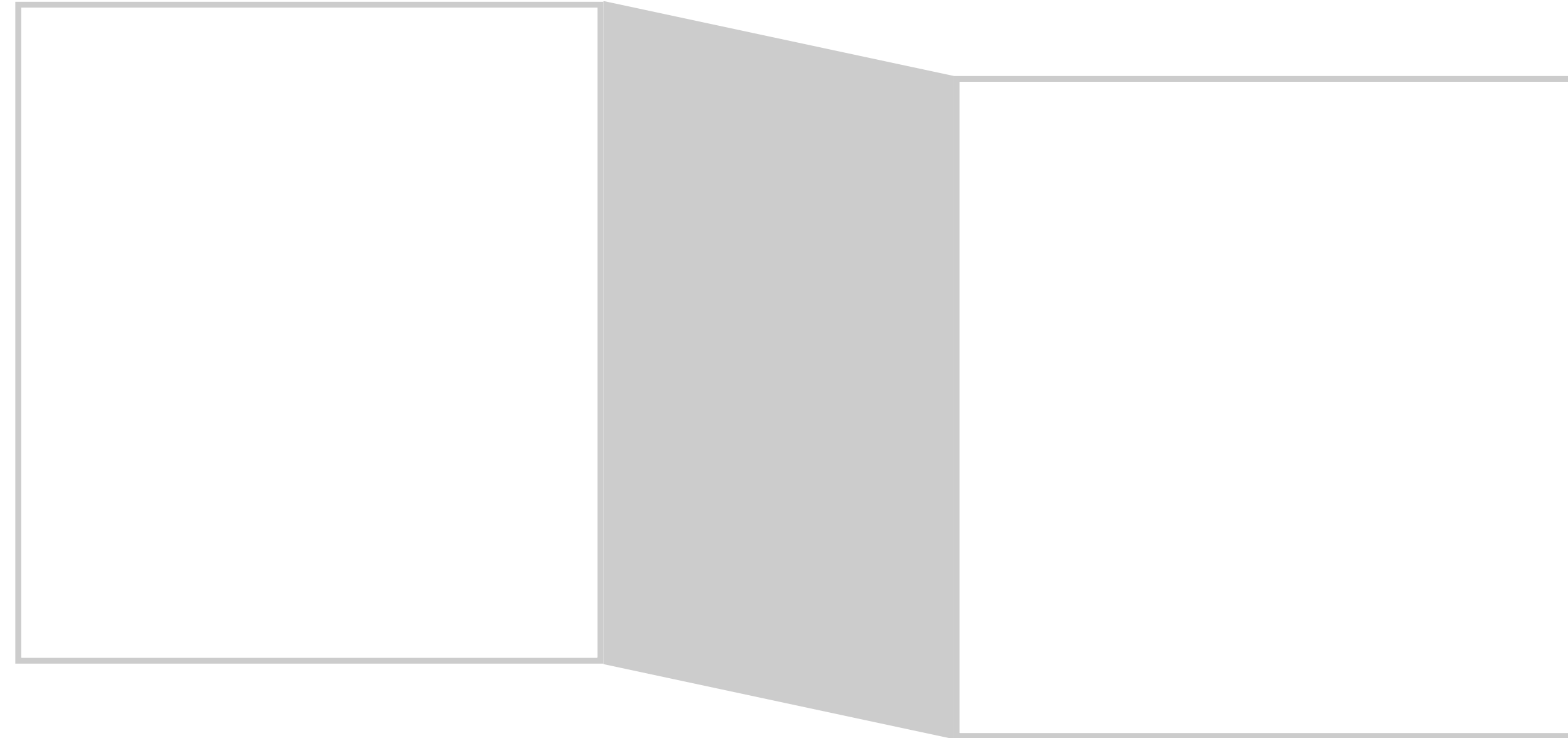
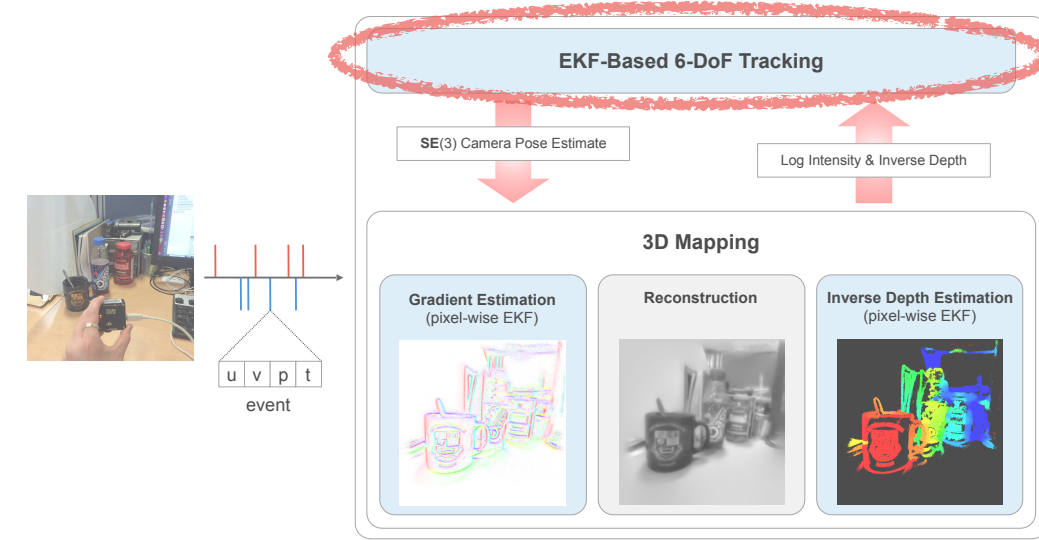
real-time 6-DoF tracking and 3D reconstruction method purely based on a stream of events

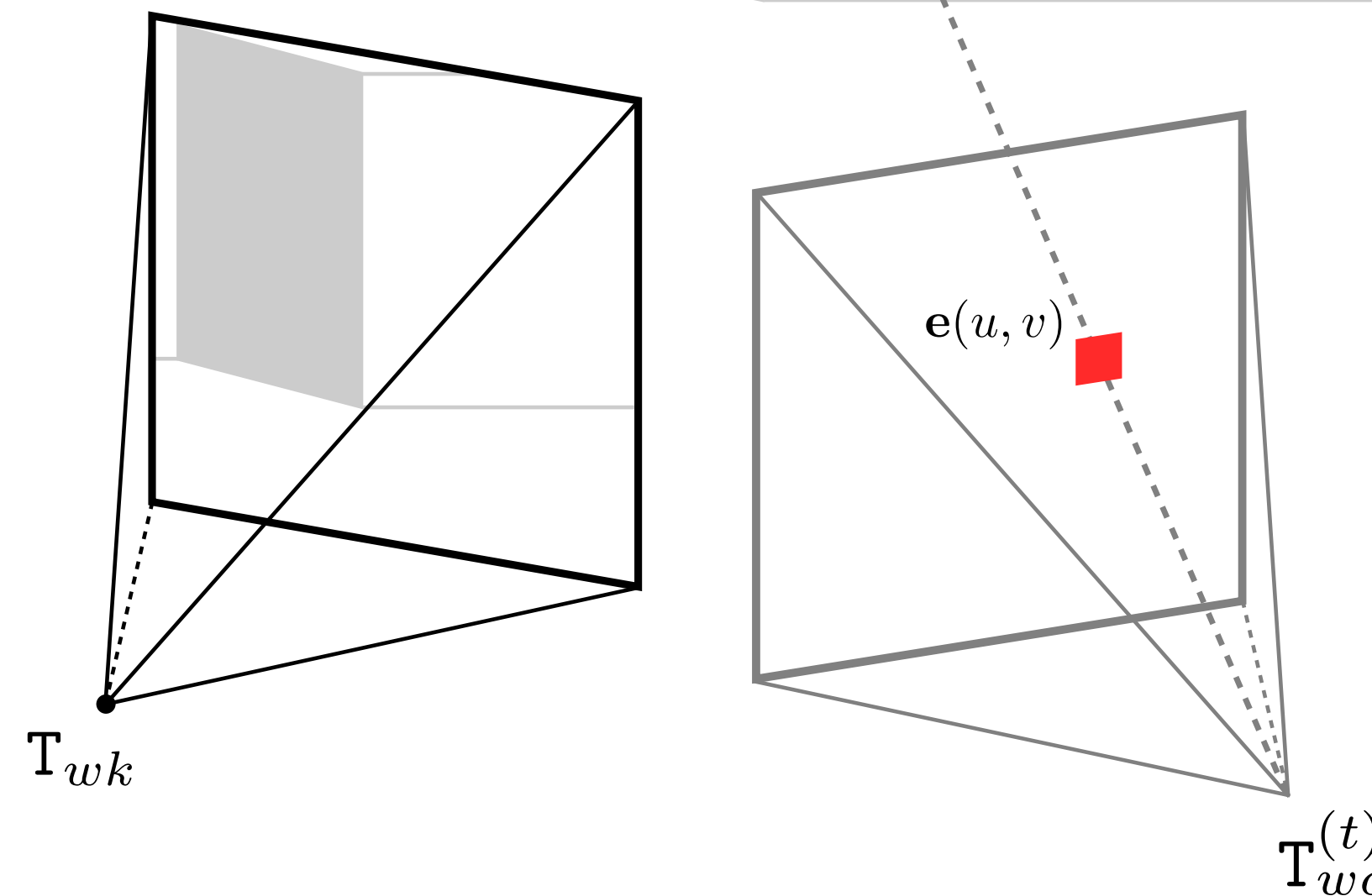
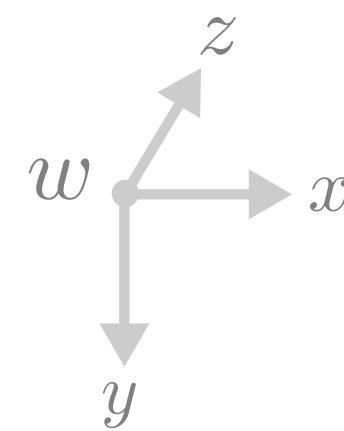
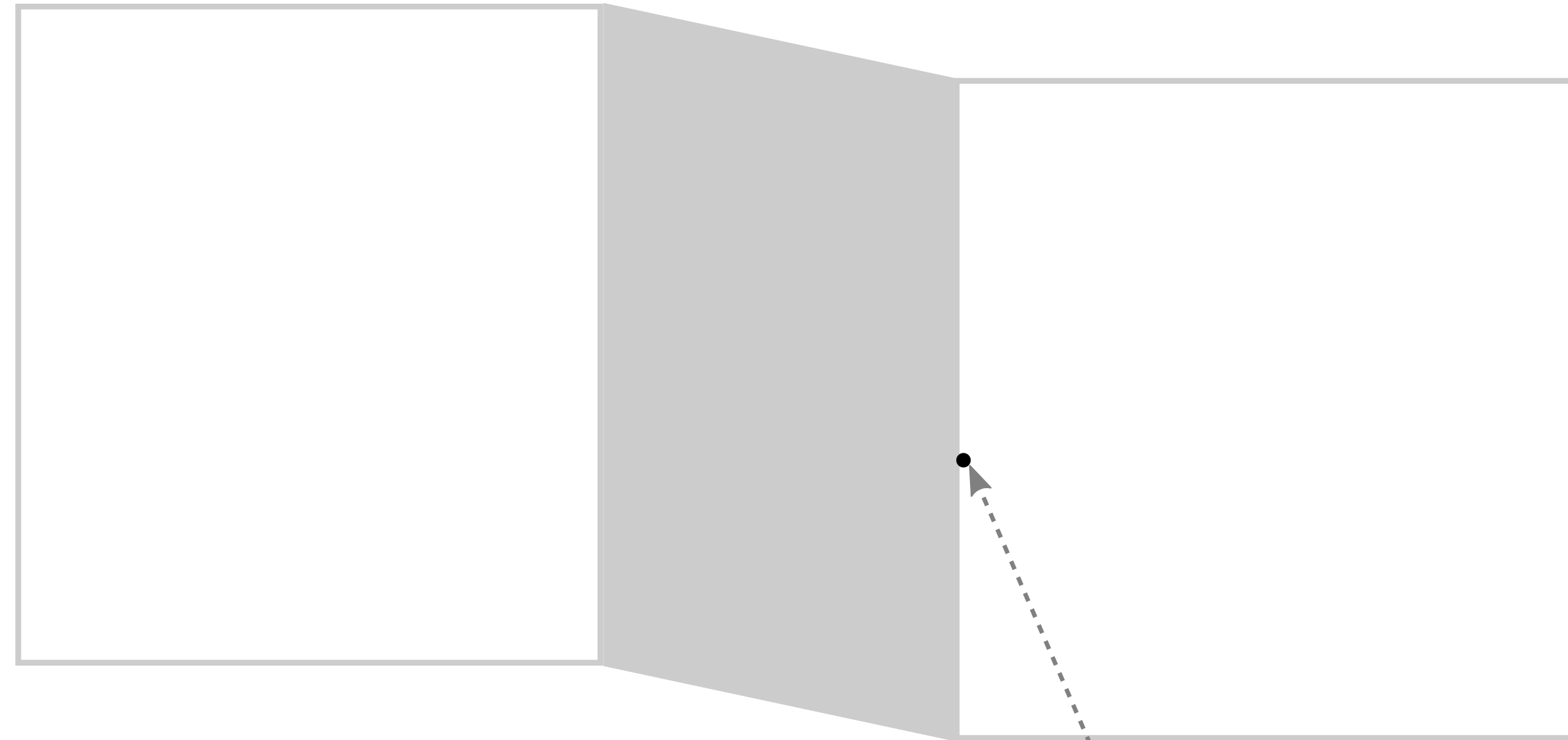
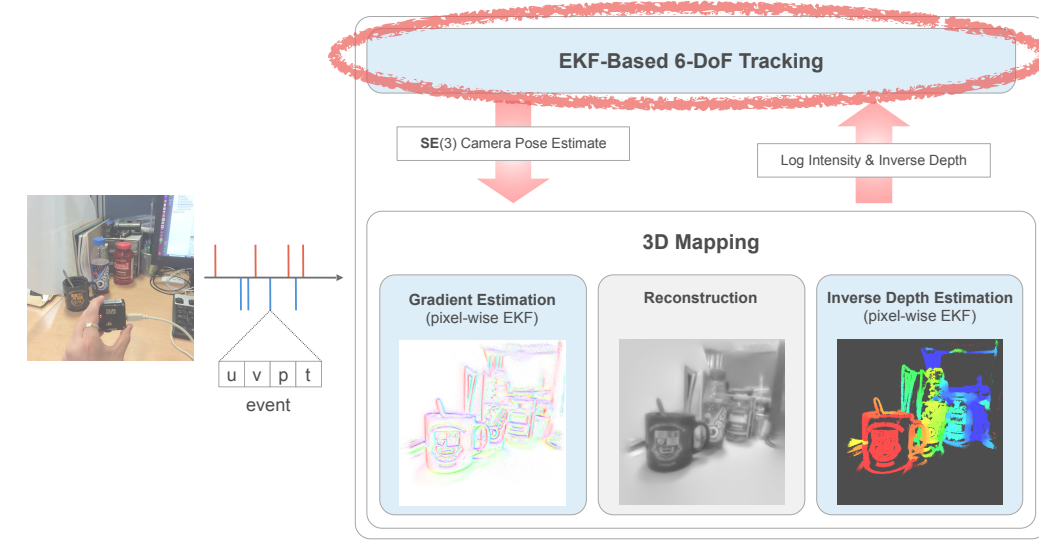


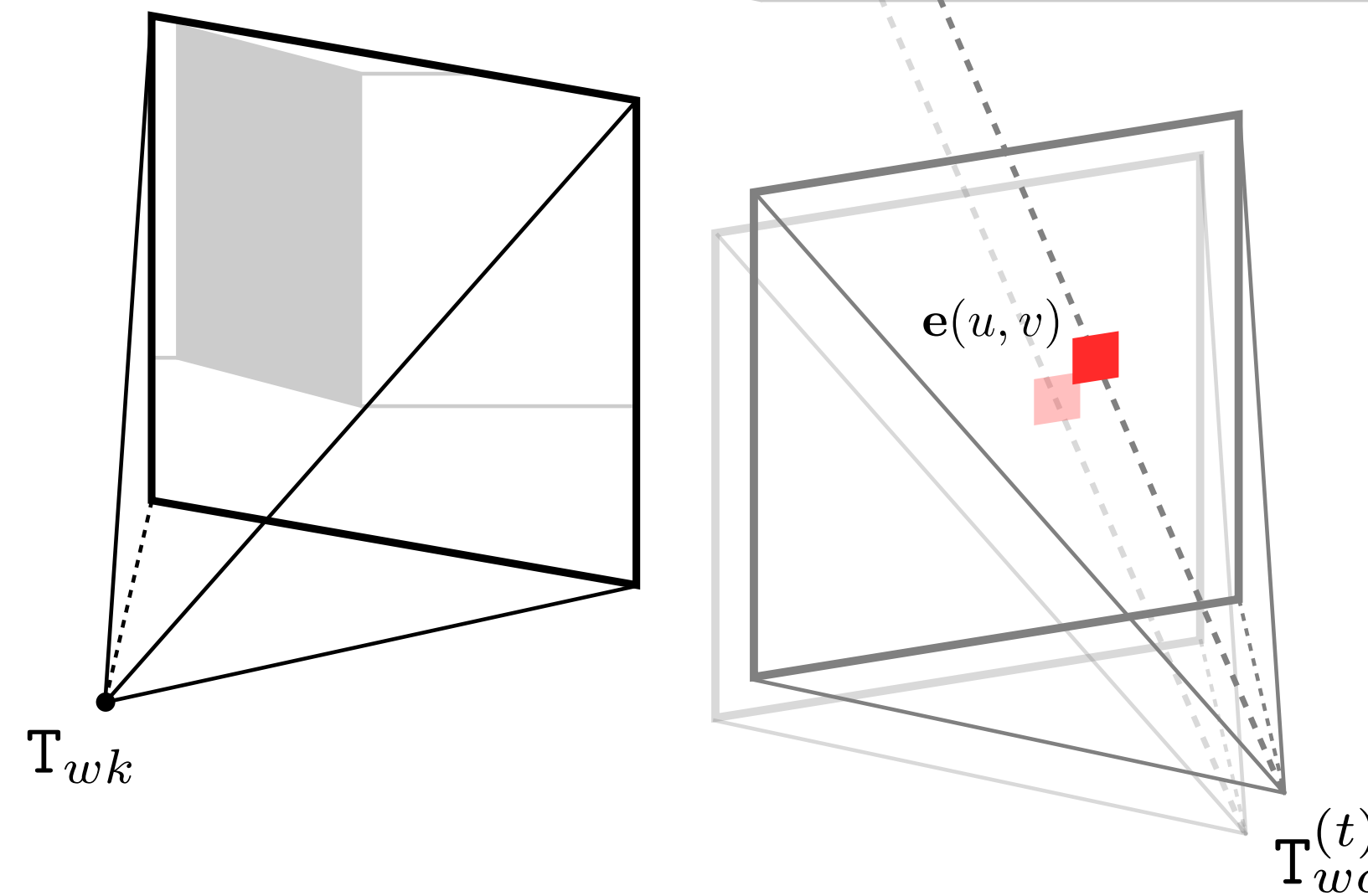
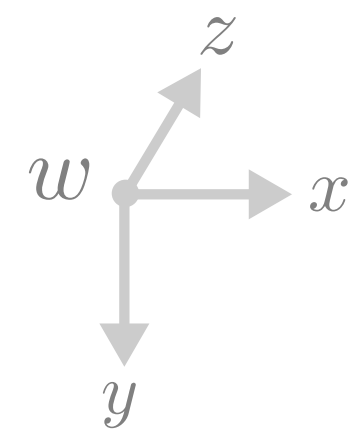
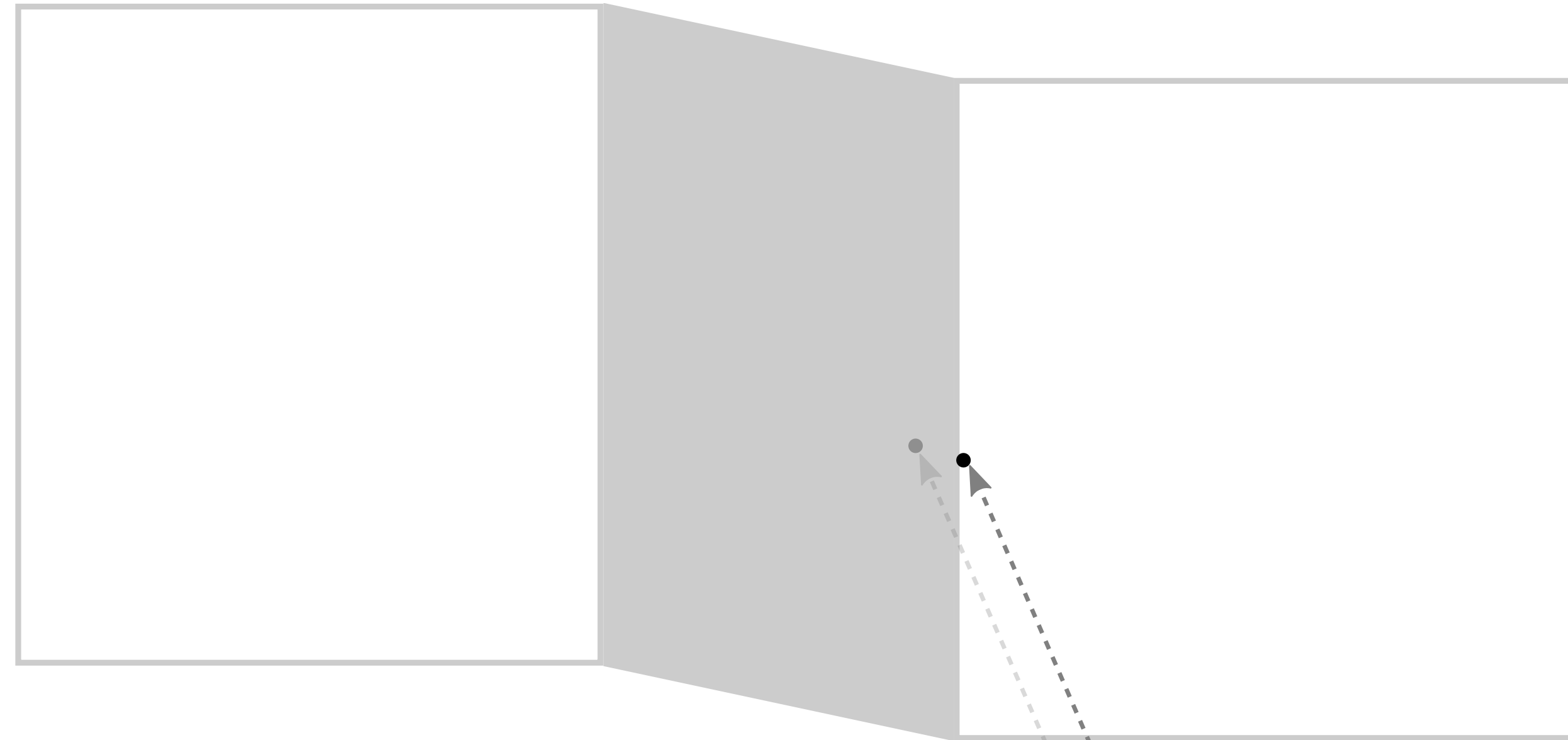
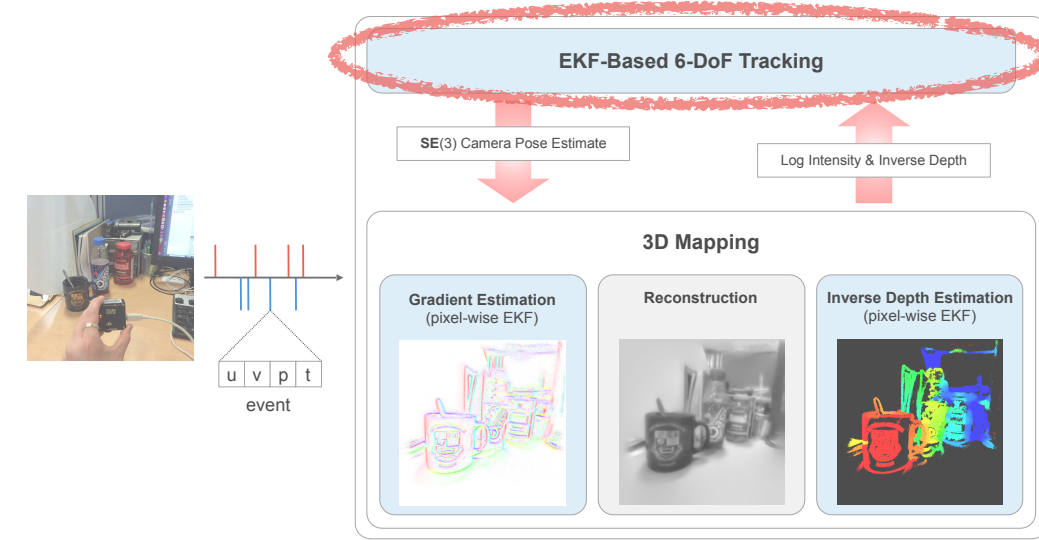
Virtual Keyframe

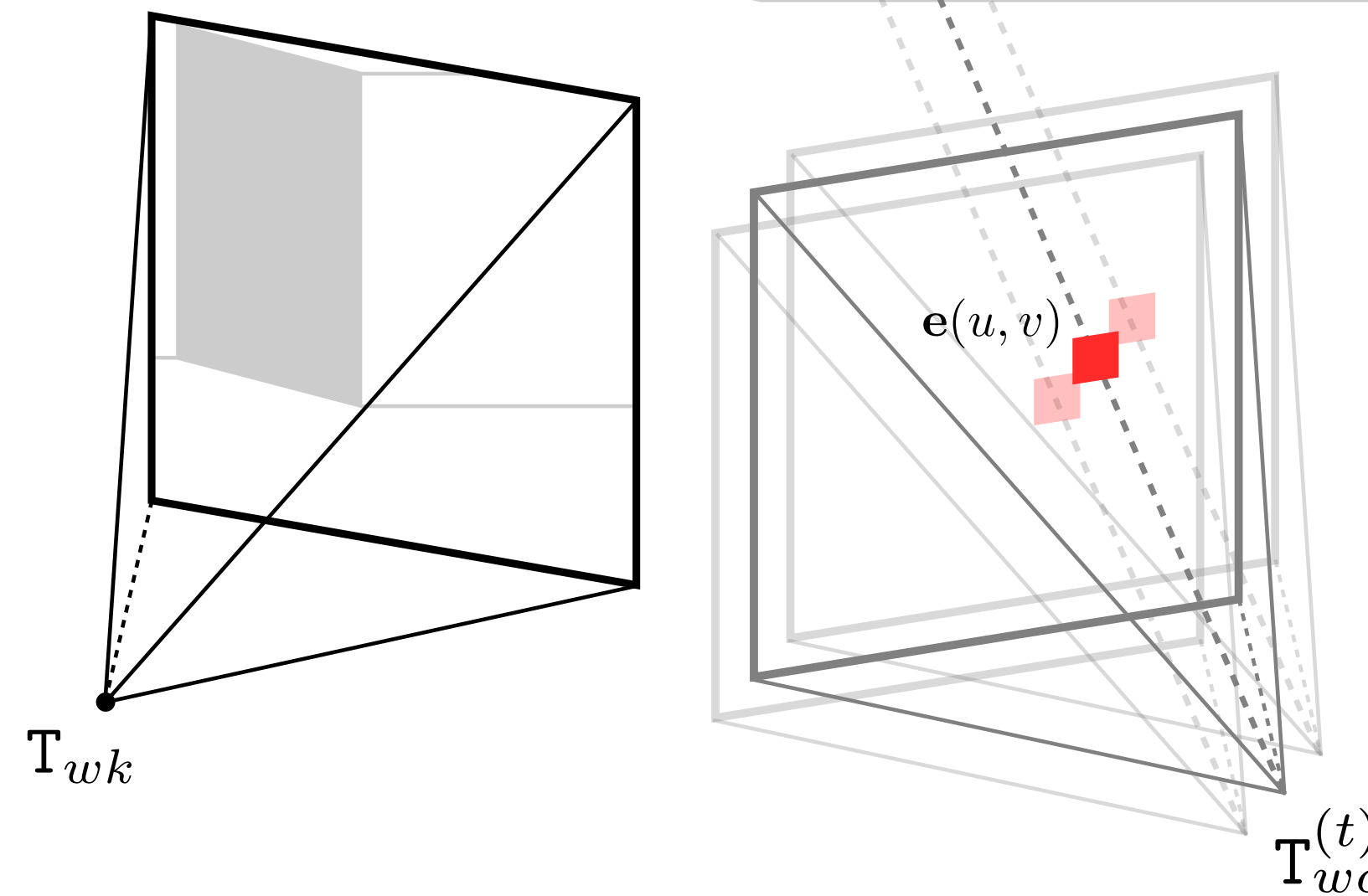
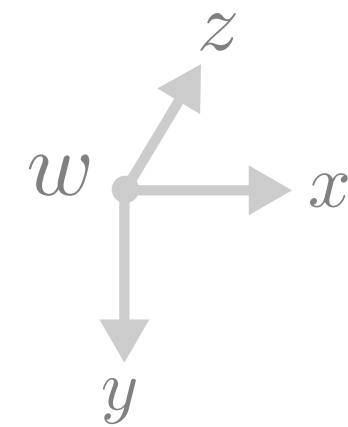
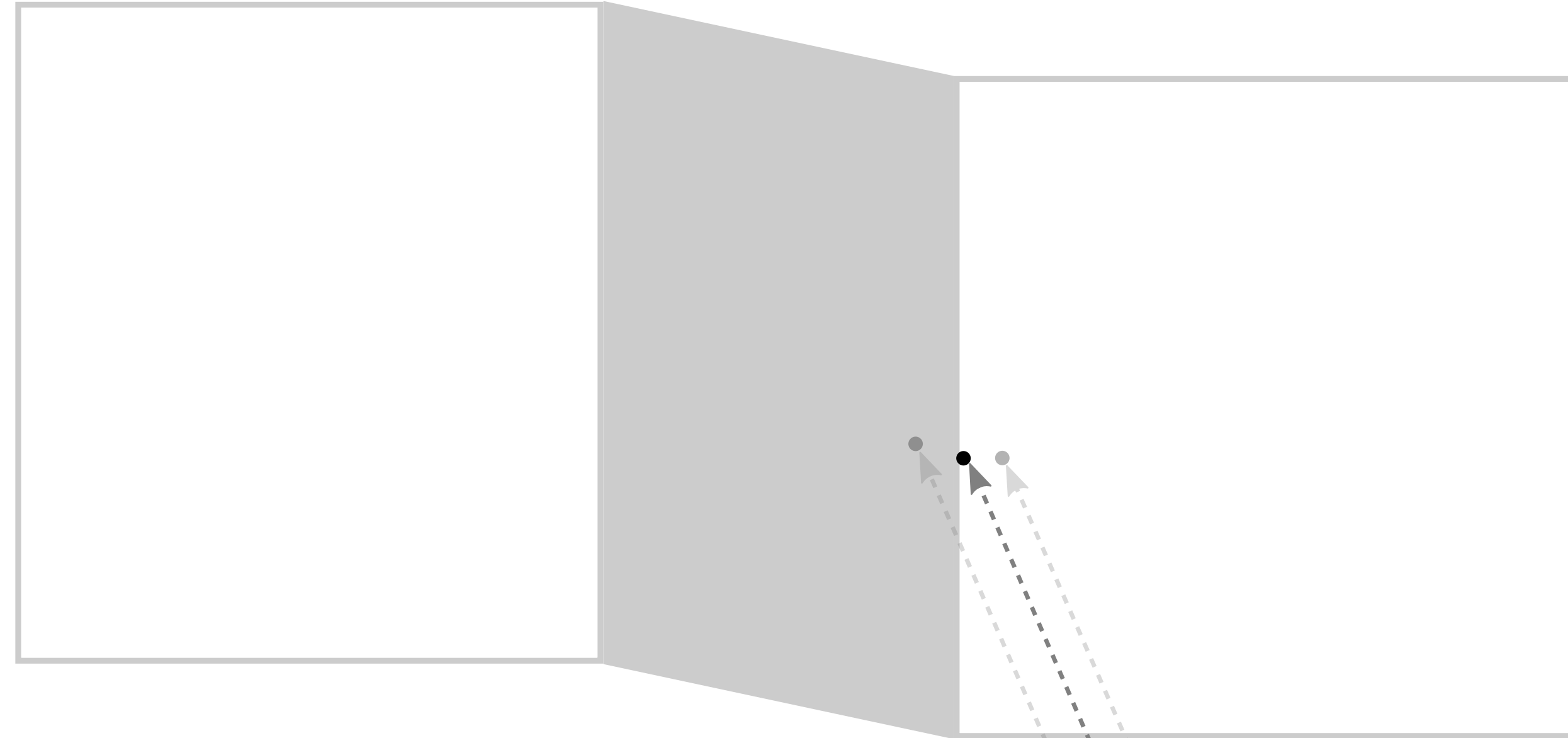
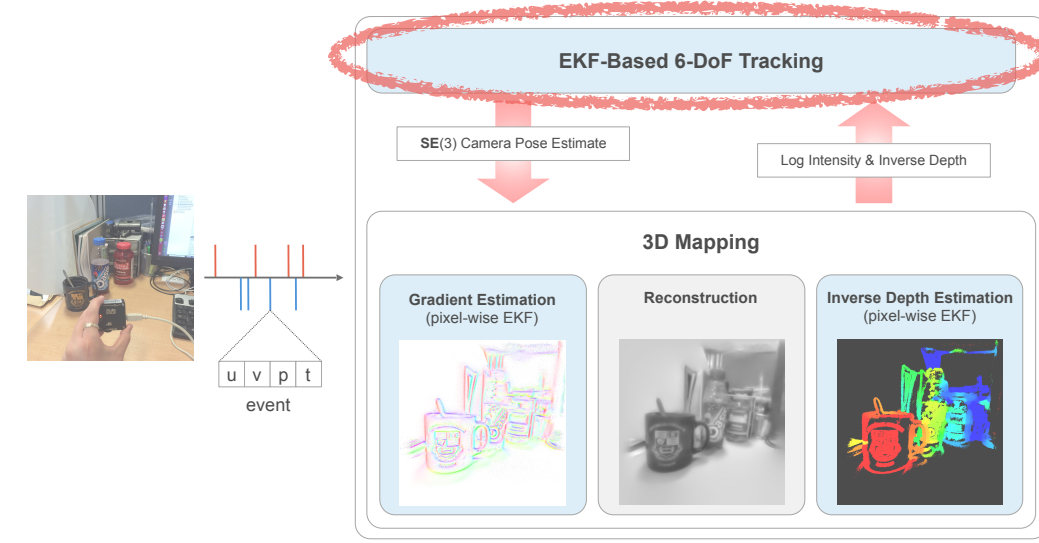
virtual projective reference frame consists of gradient, intensity and depth

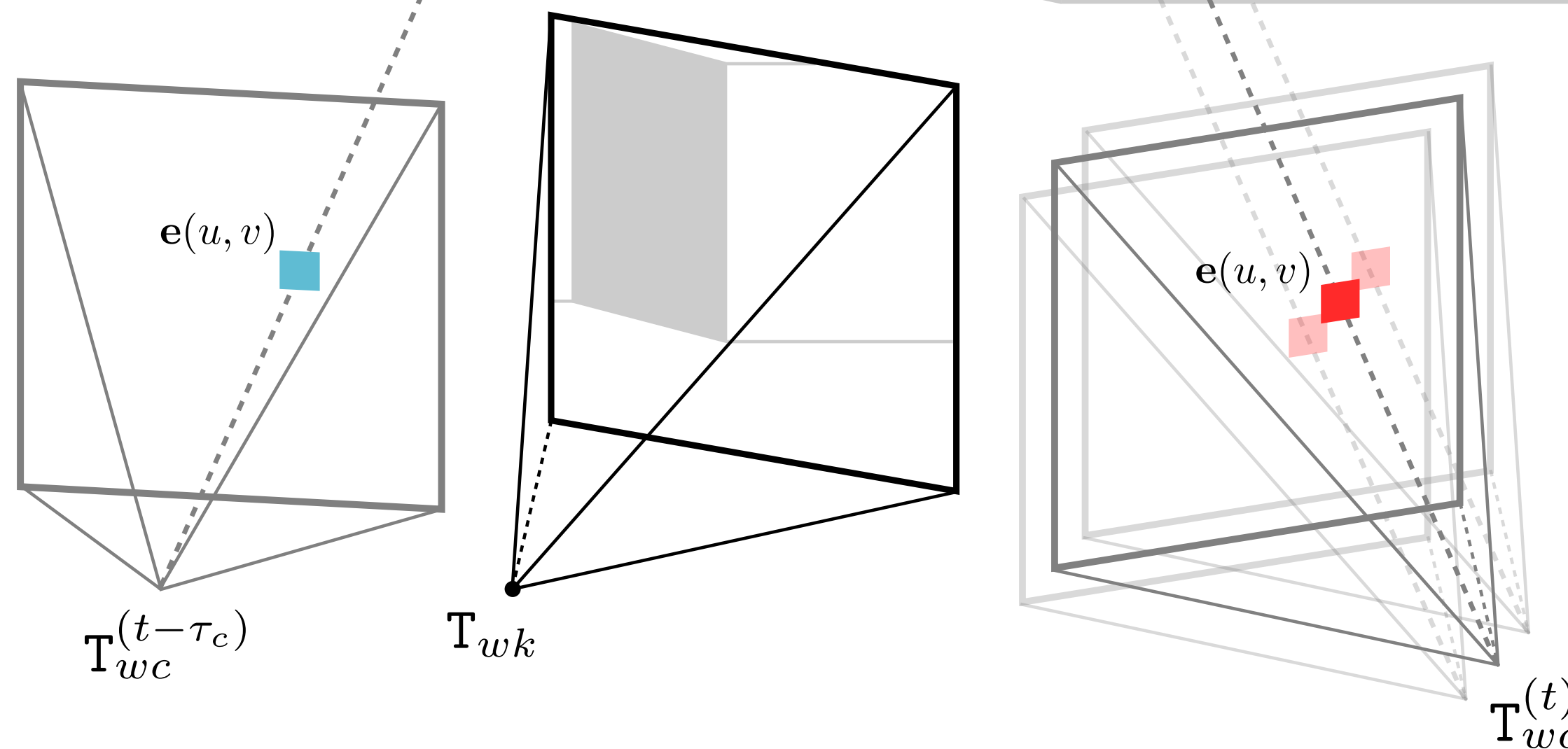
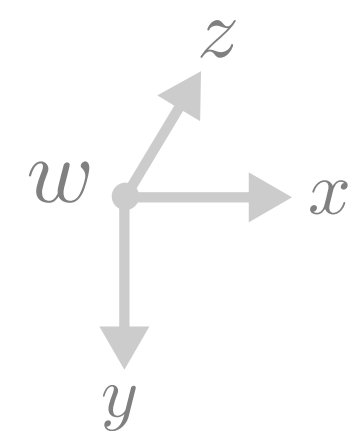
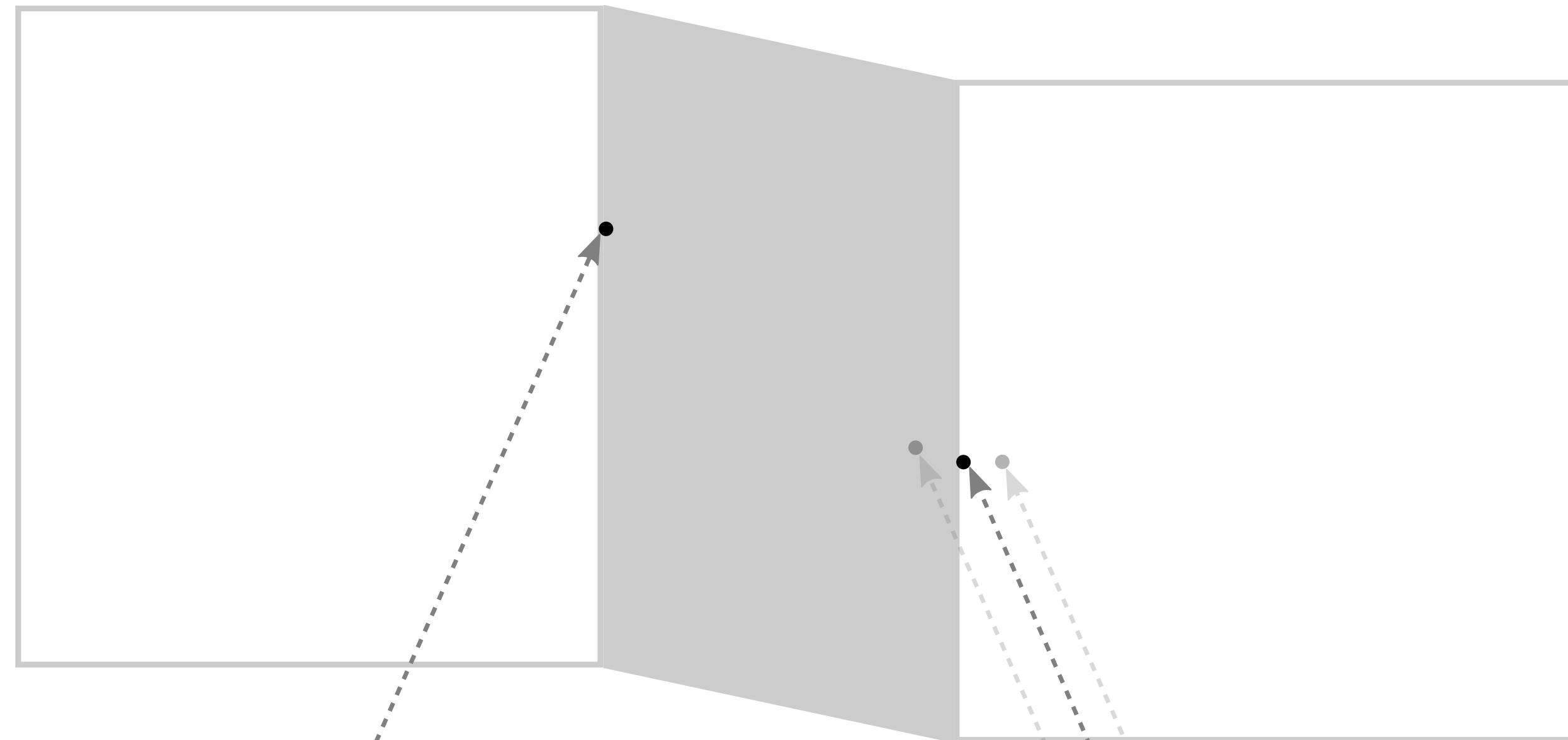
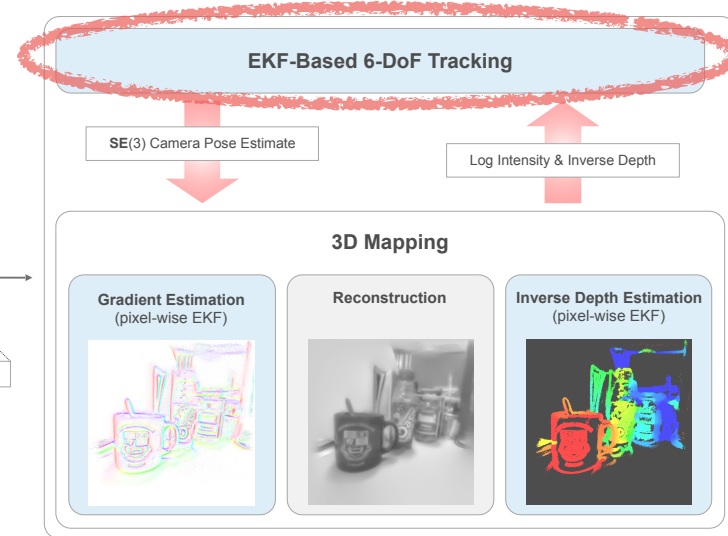


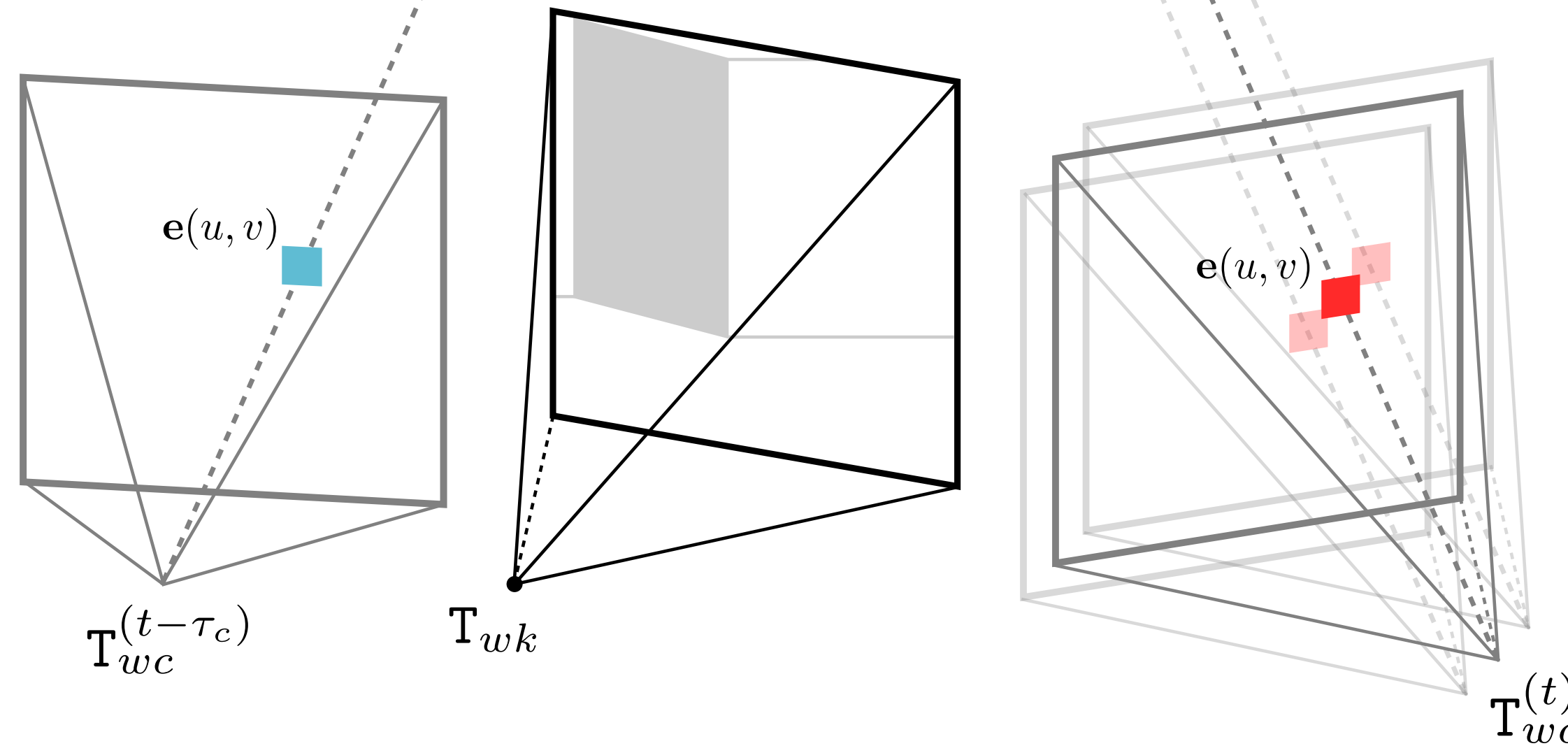
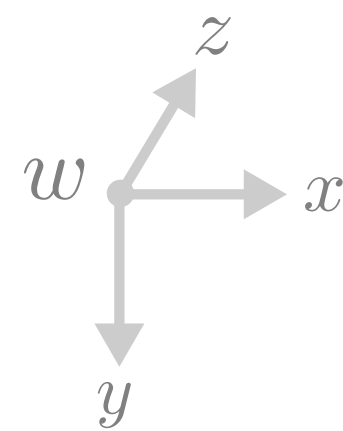
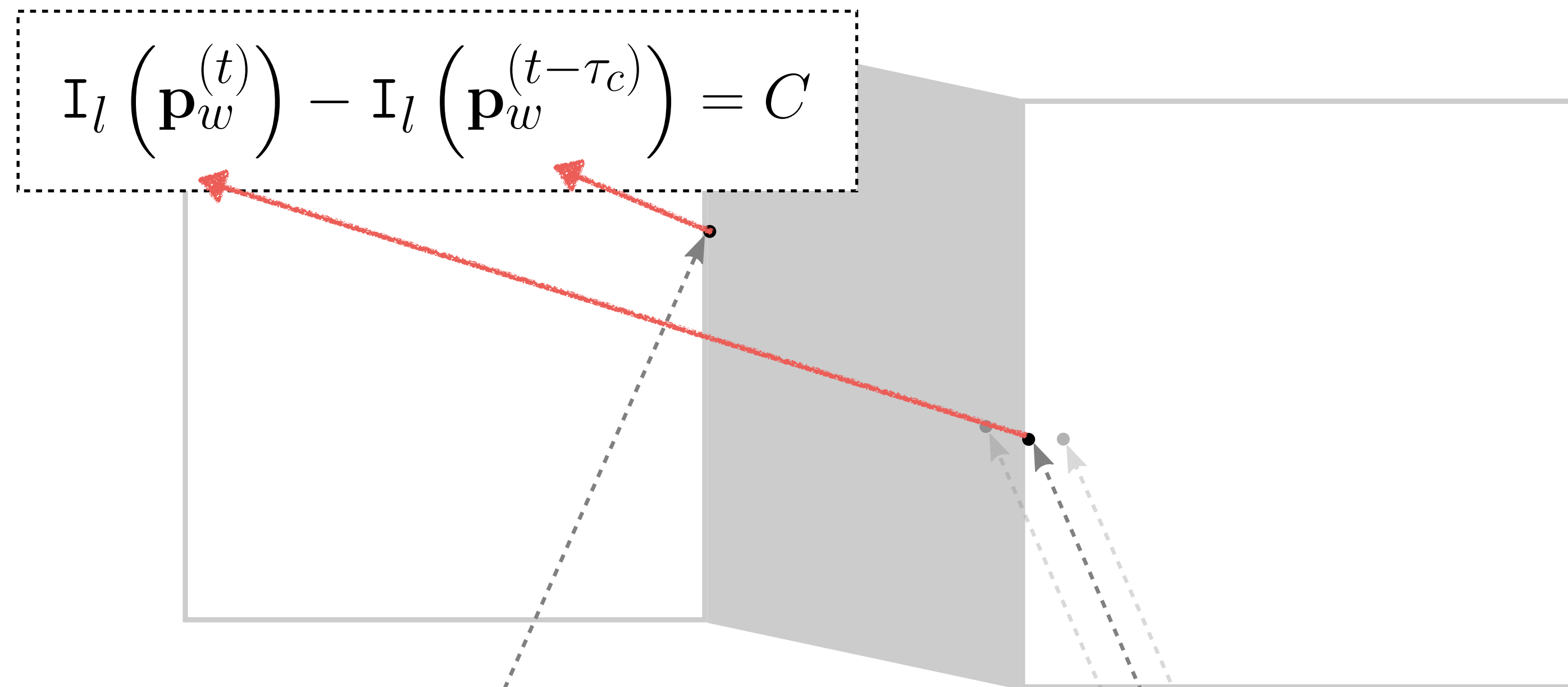
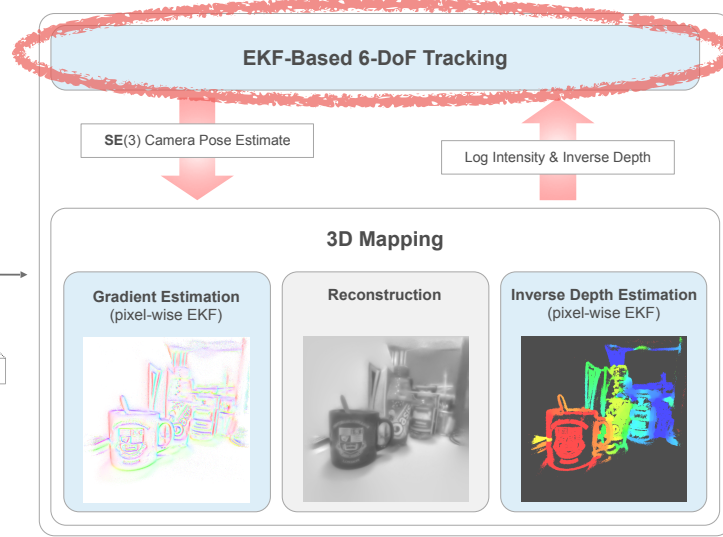


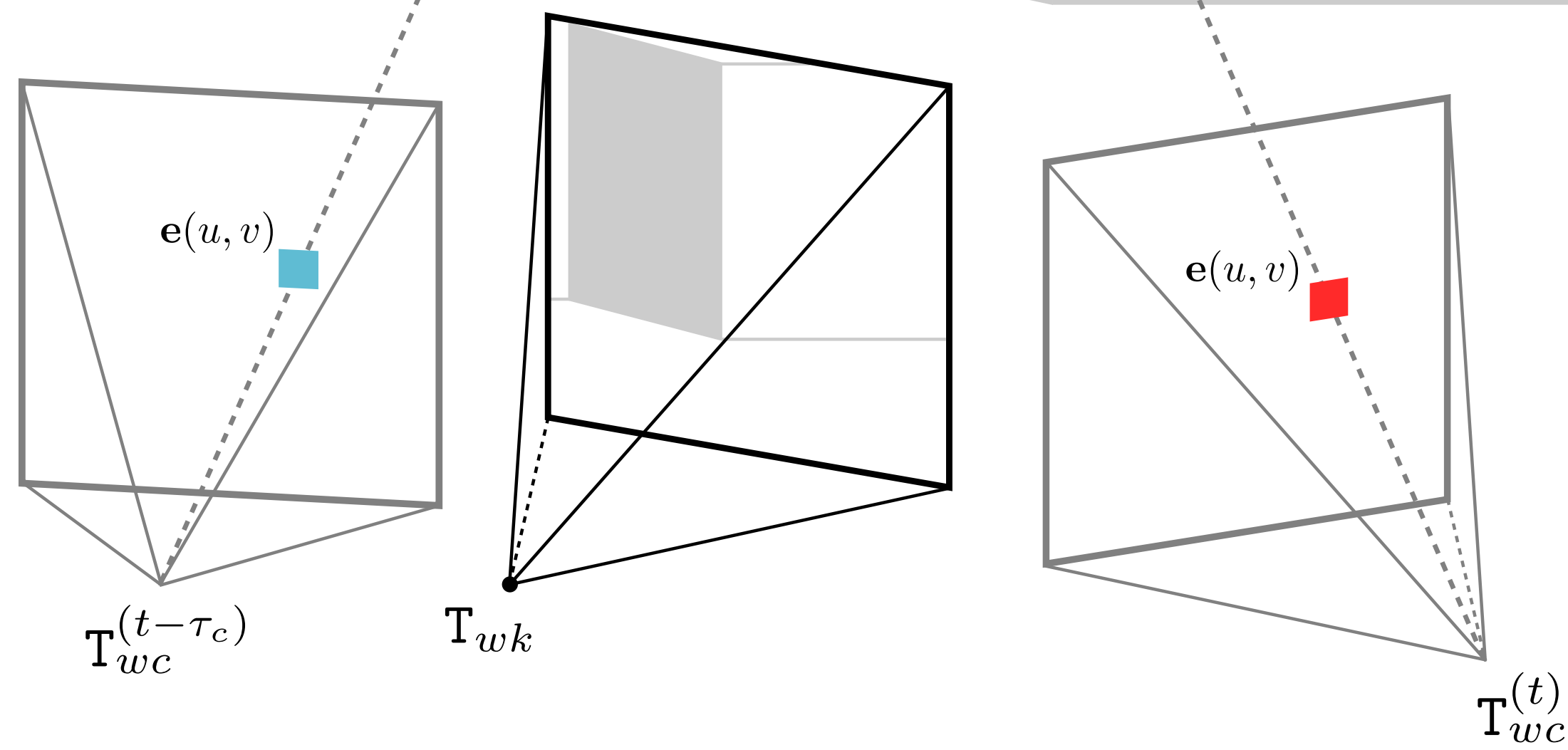
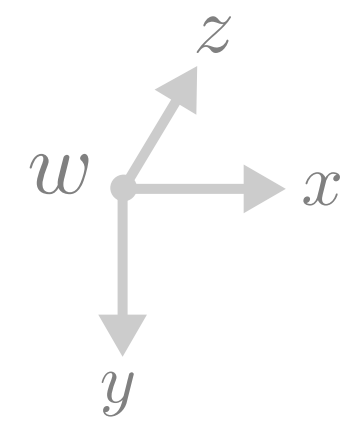
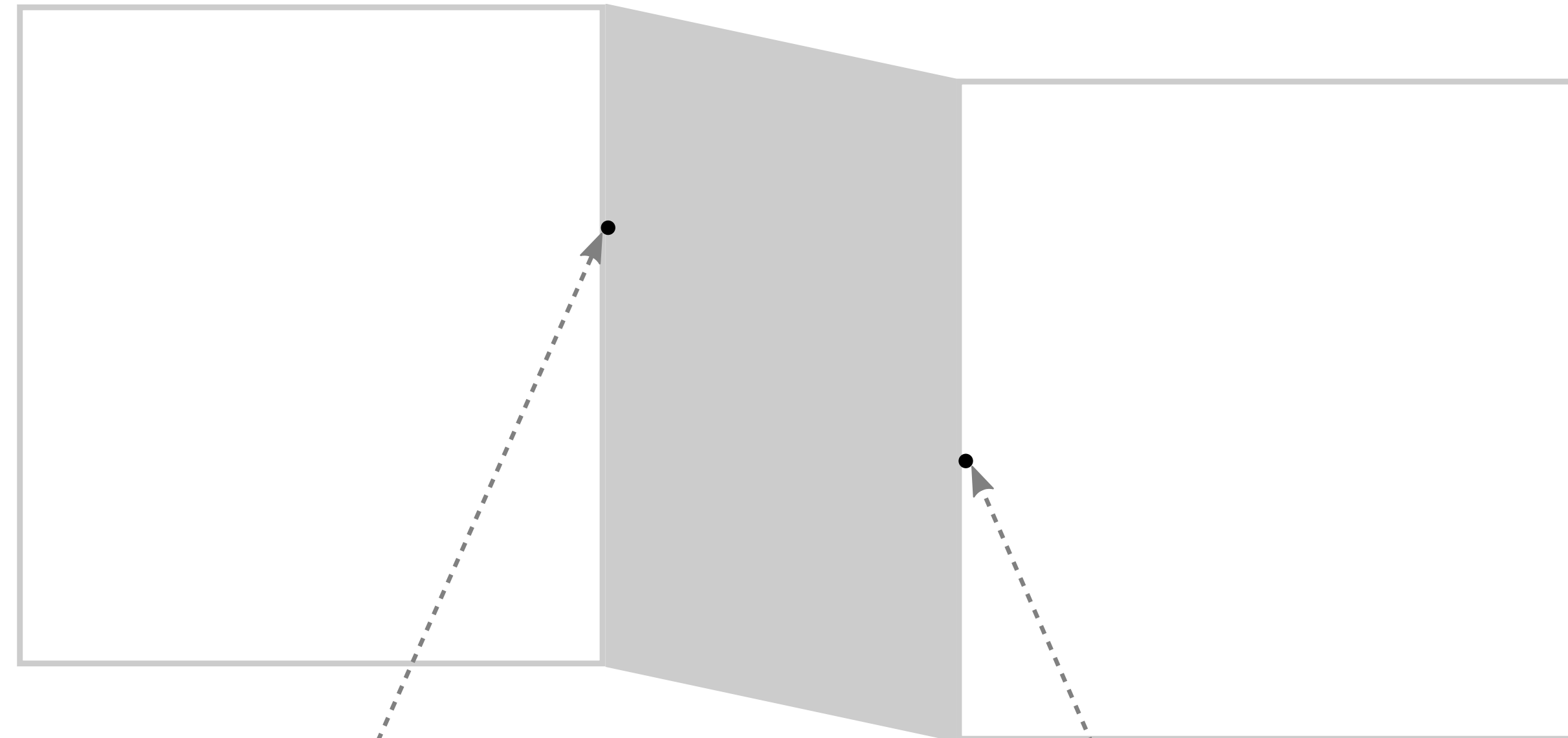
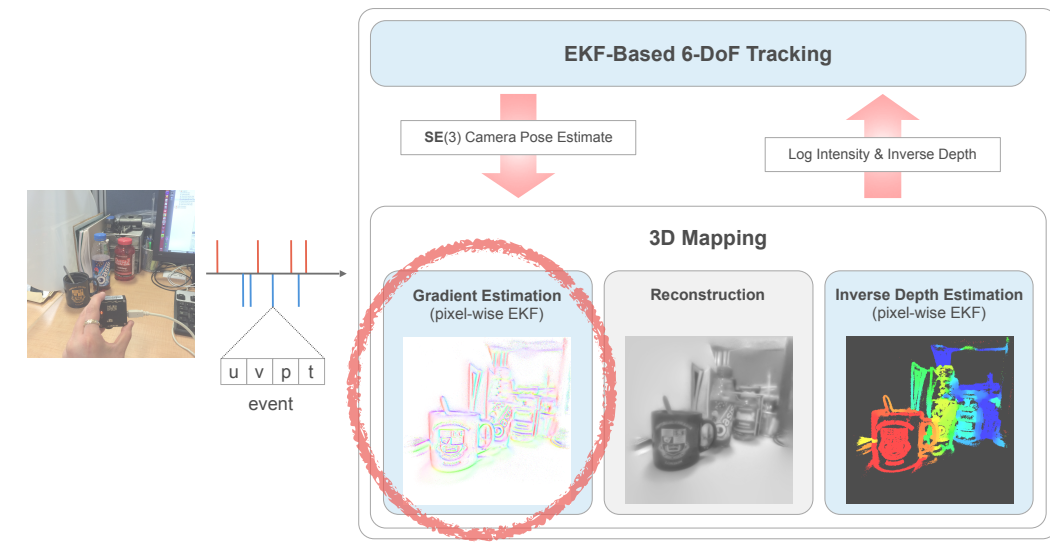


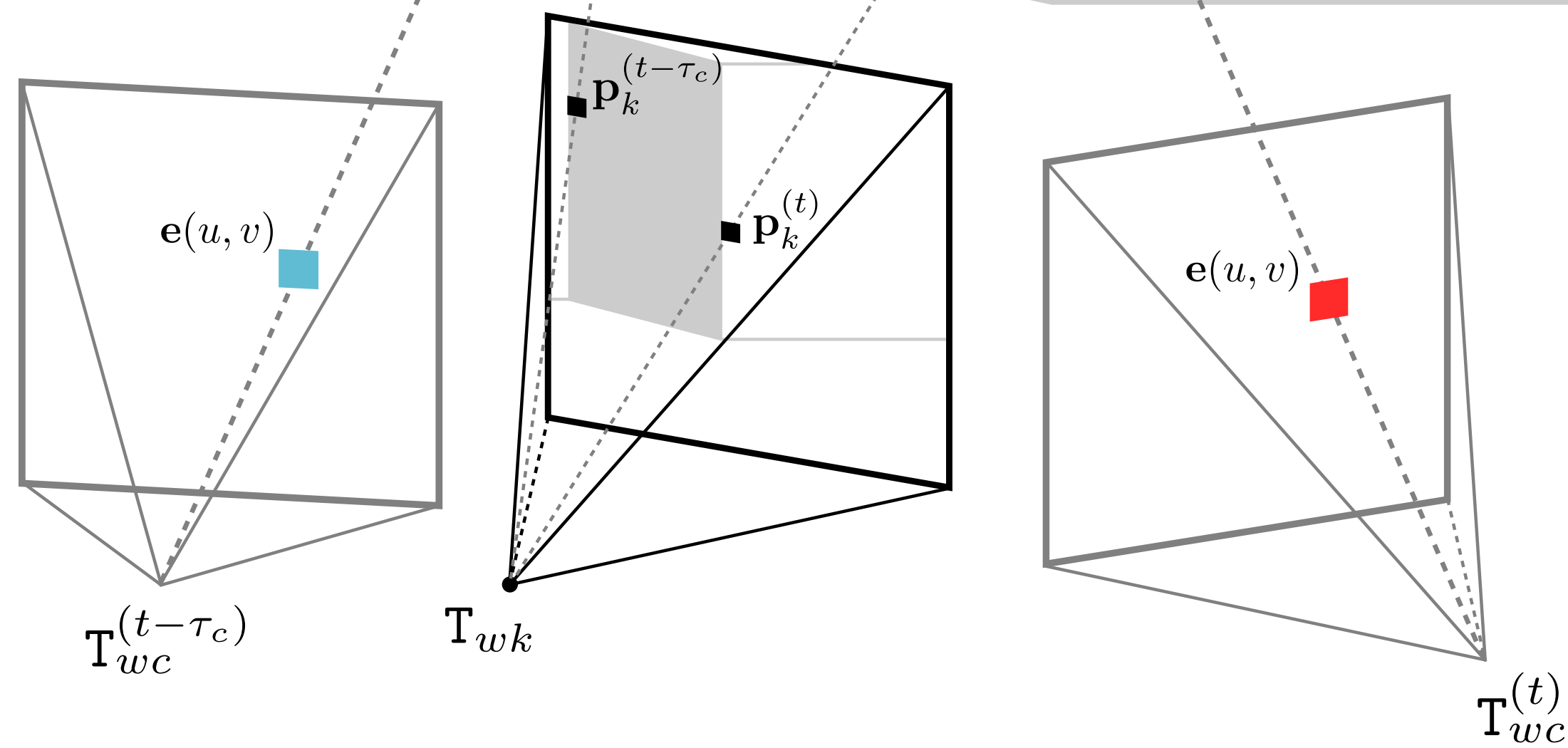
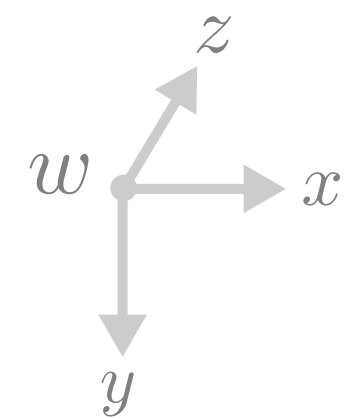
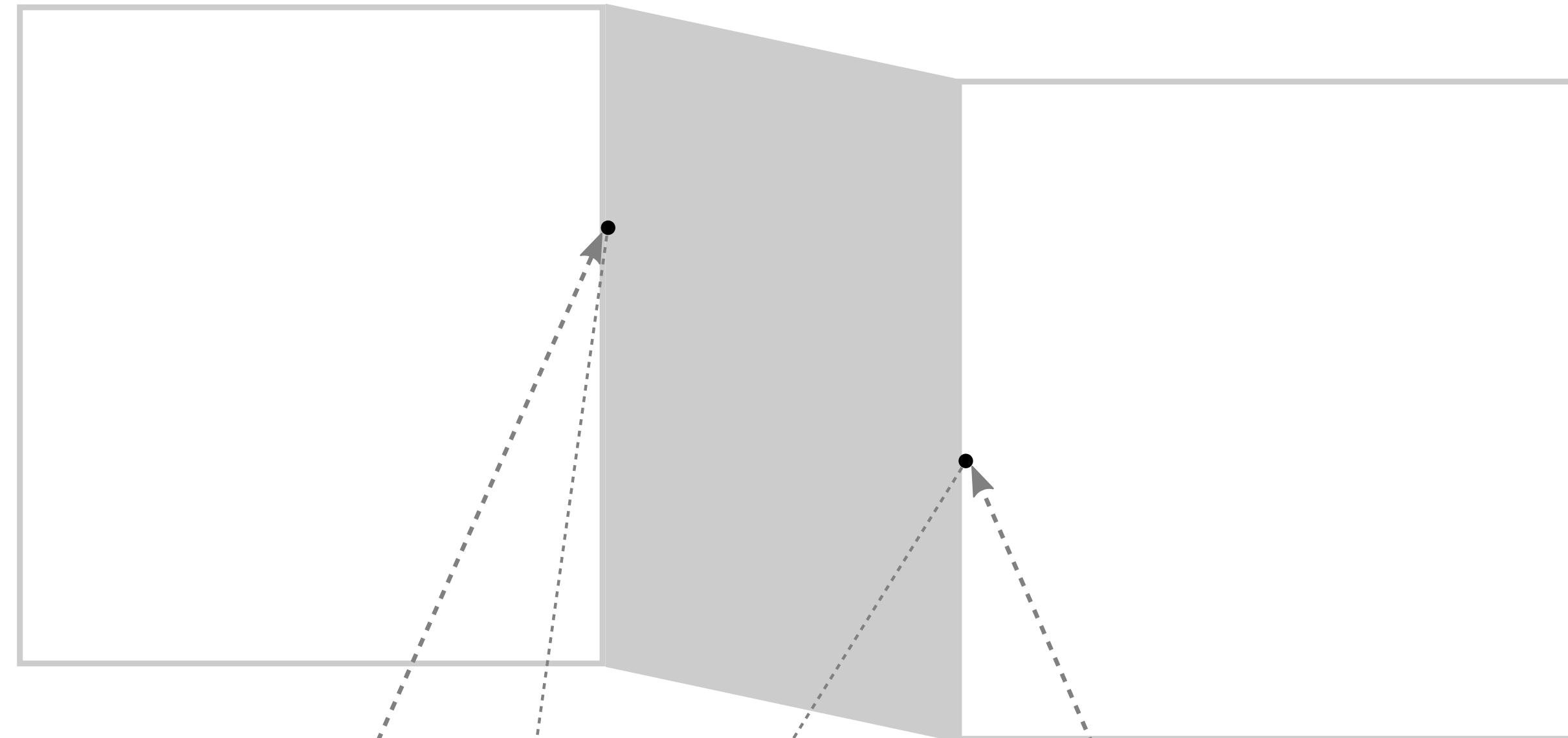
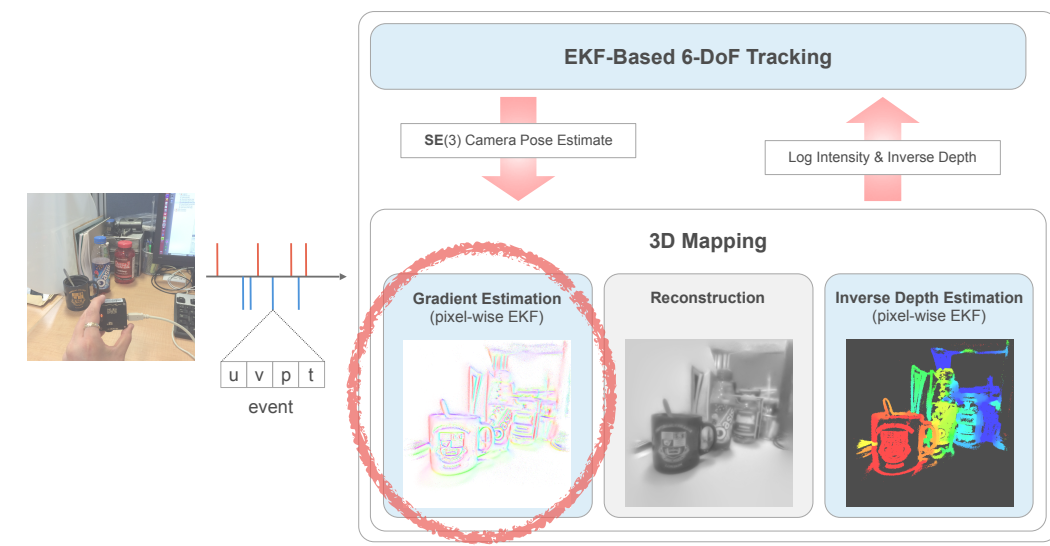


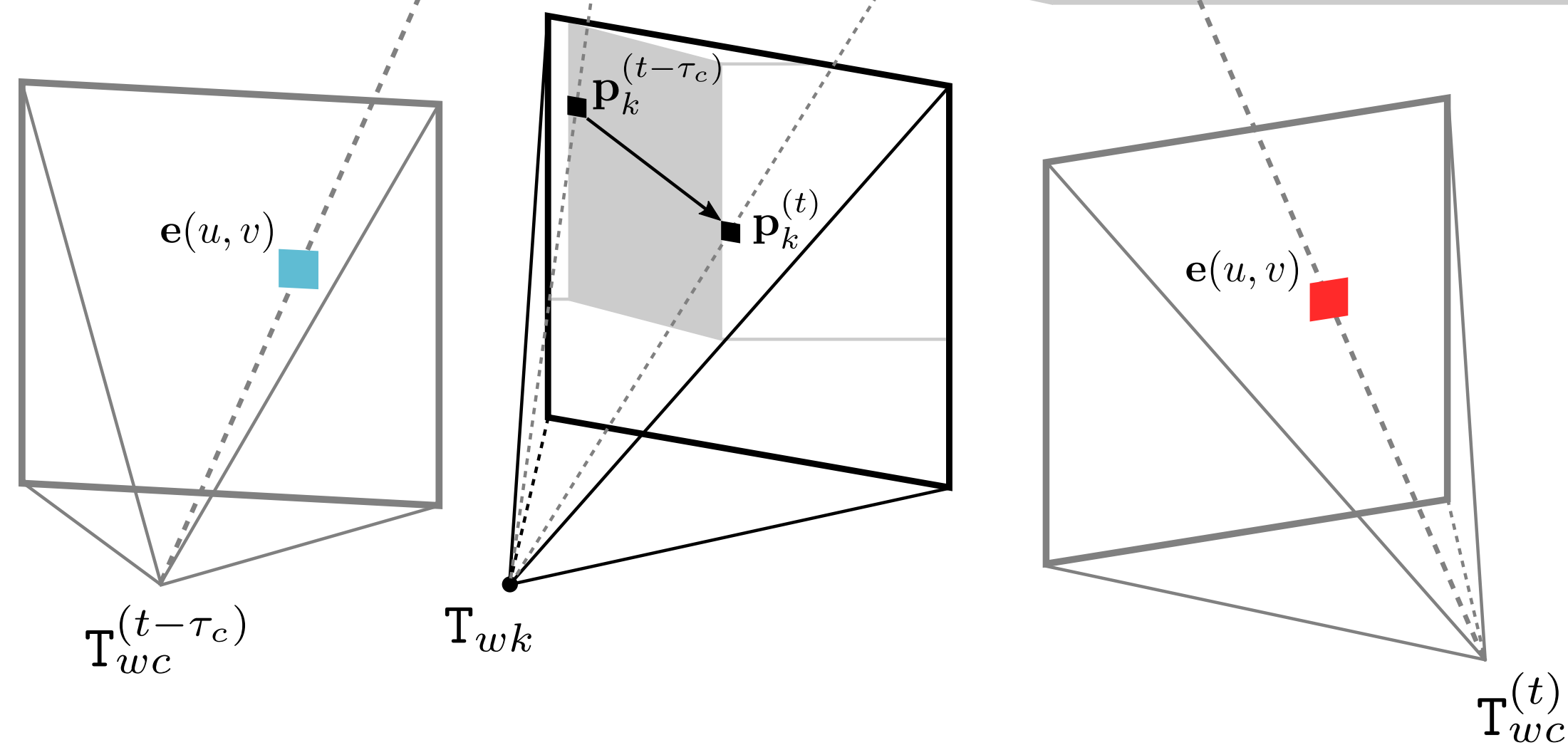
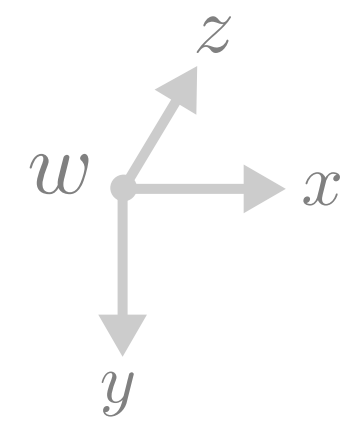
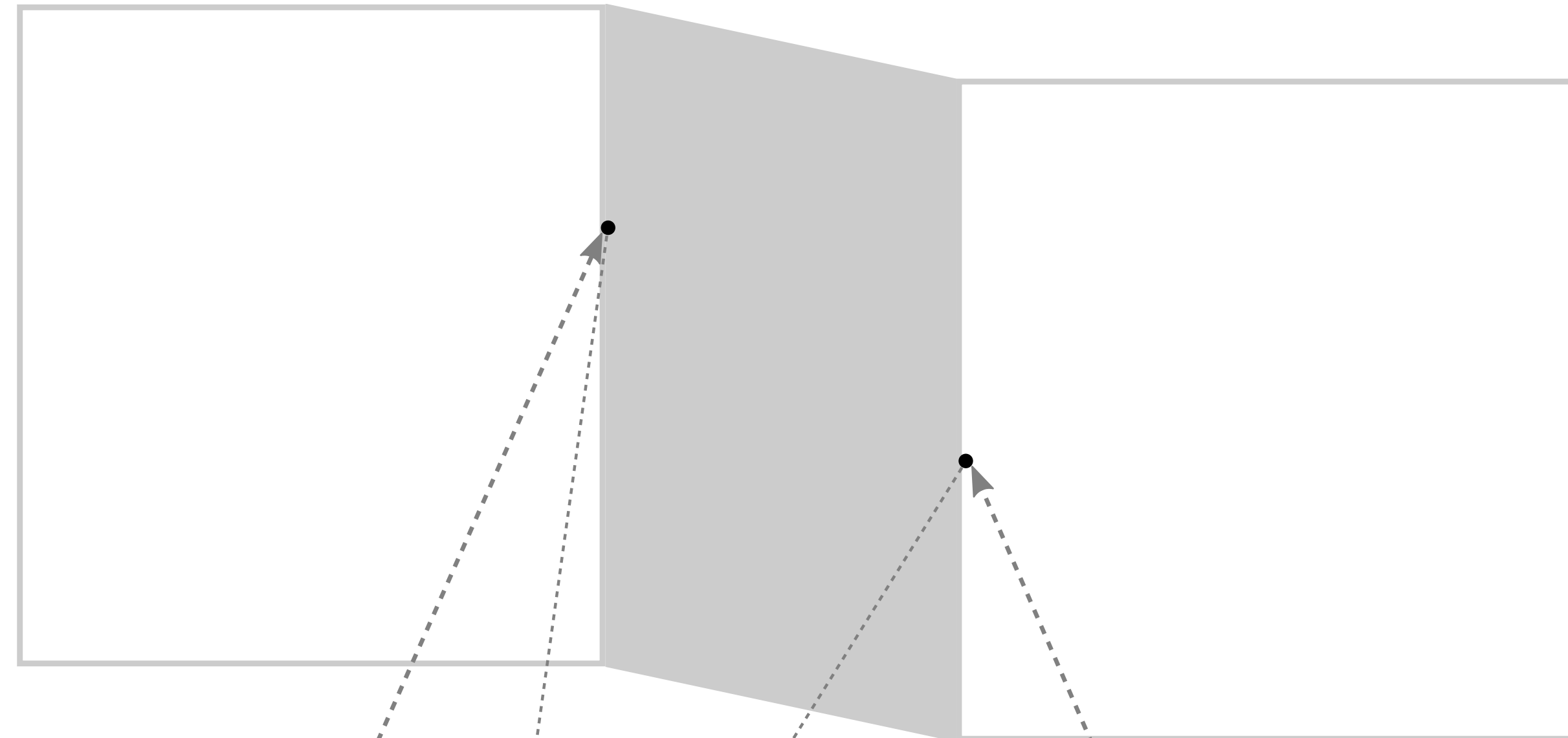
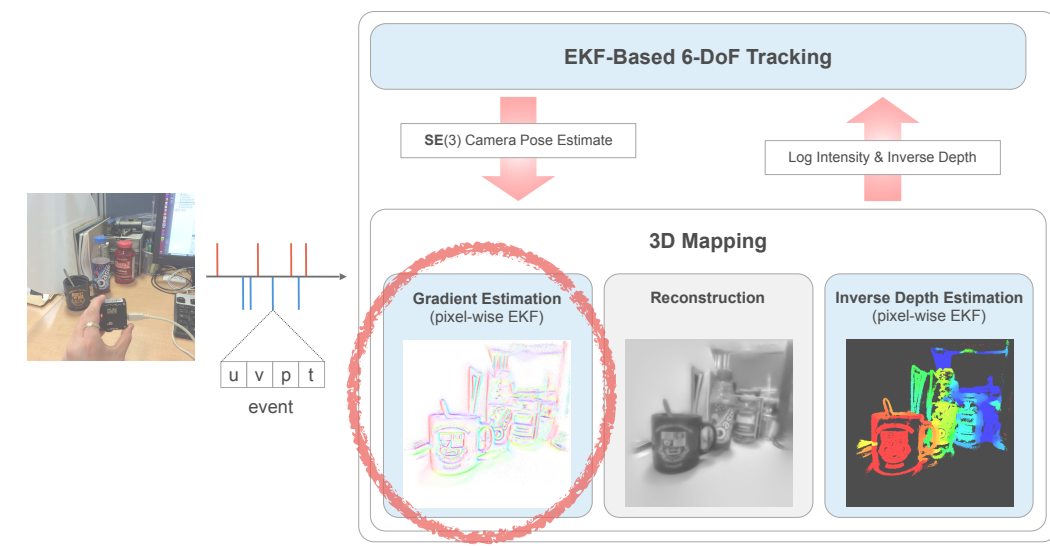


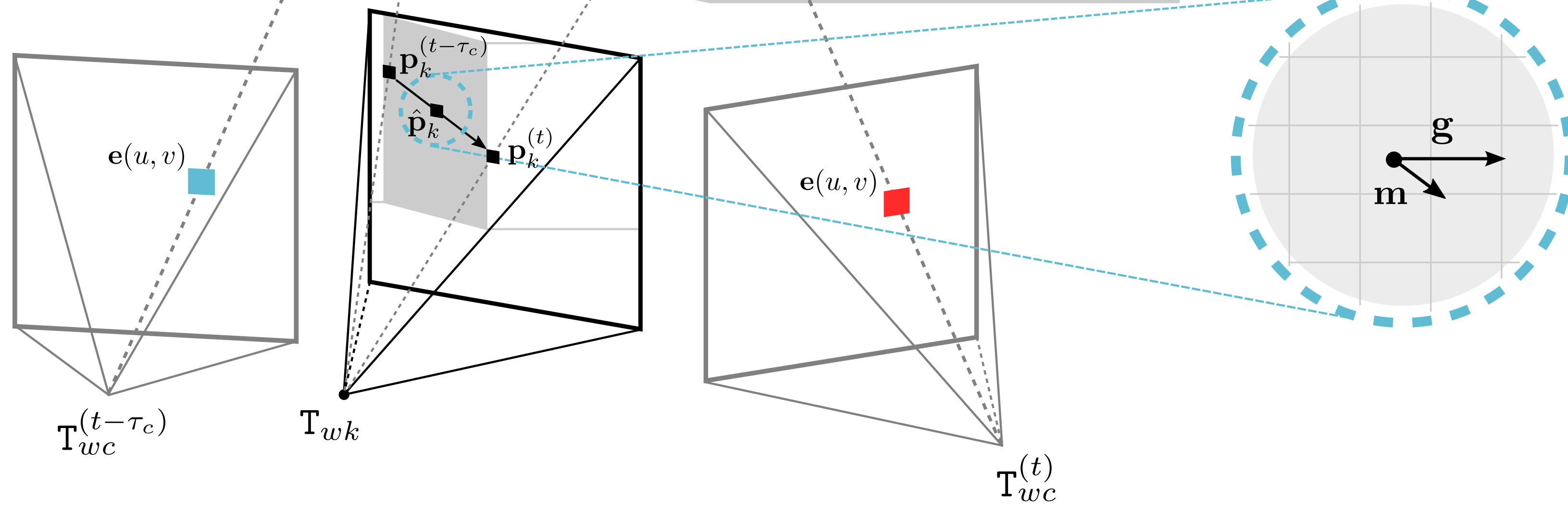
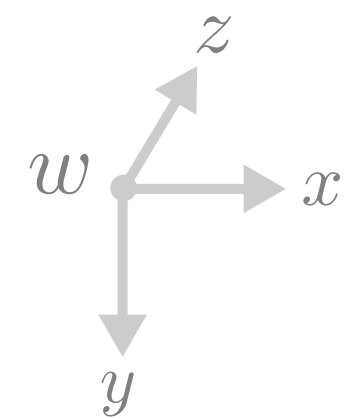
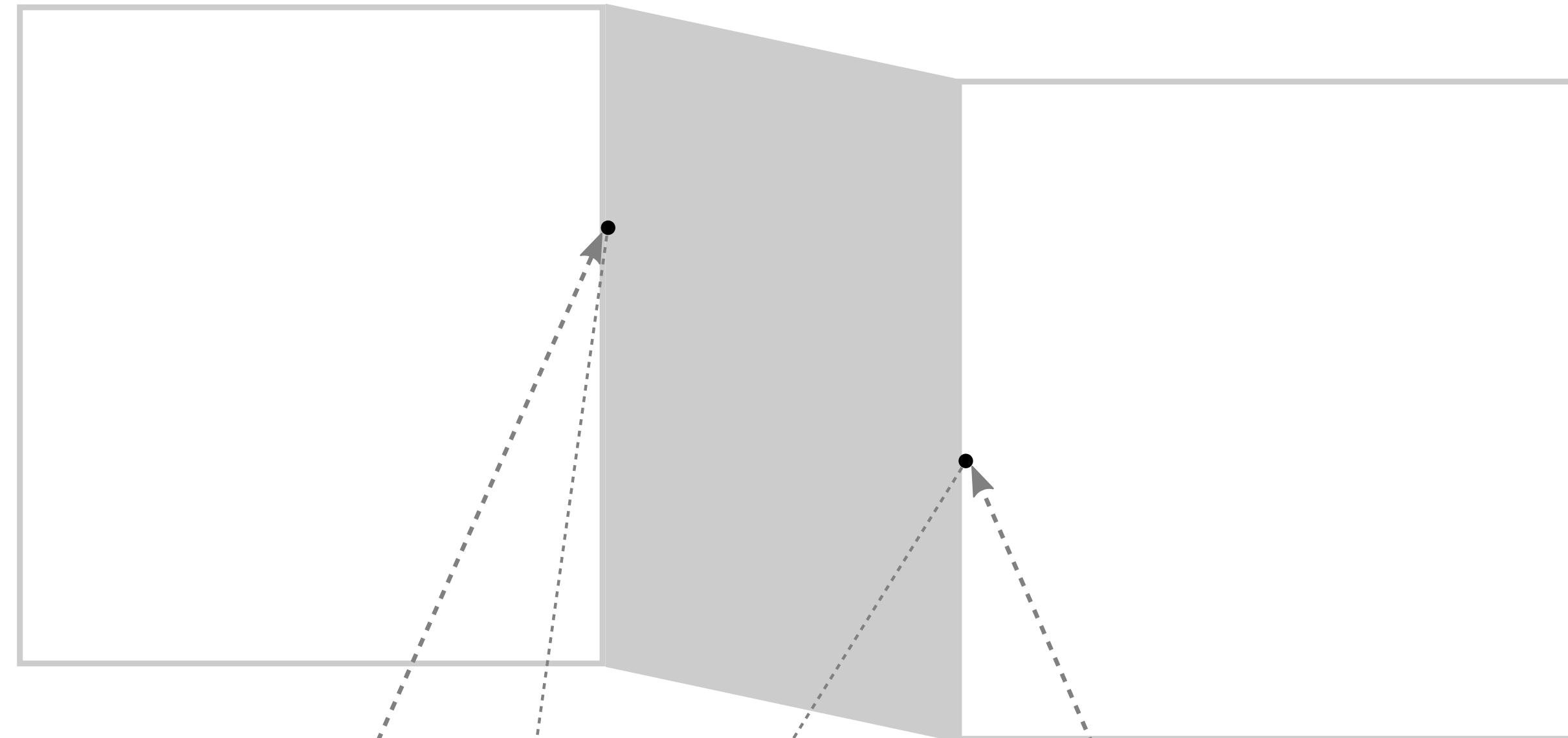
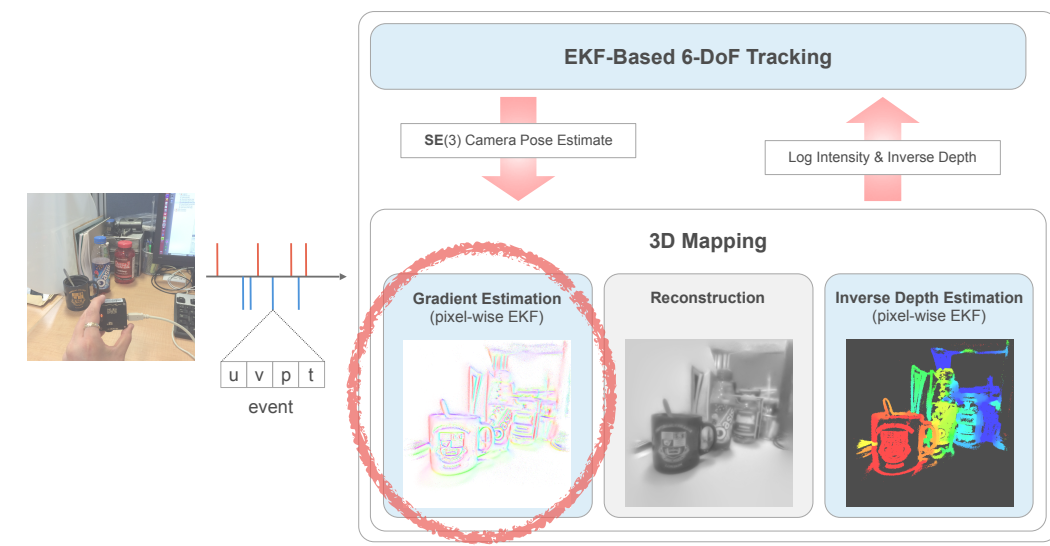




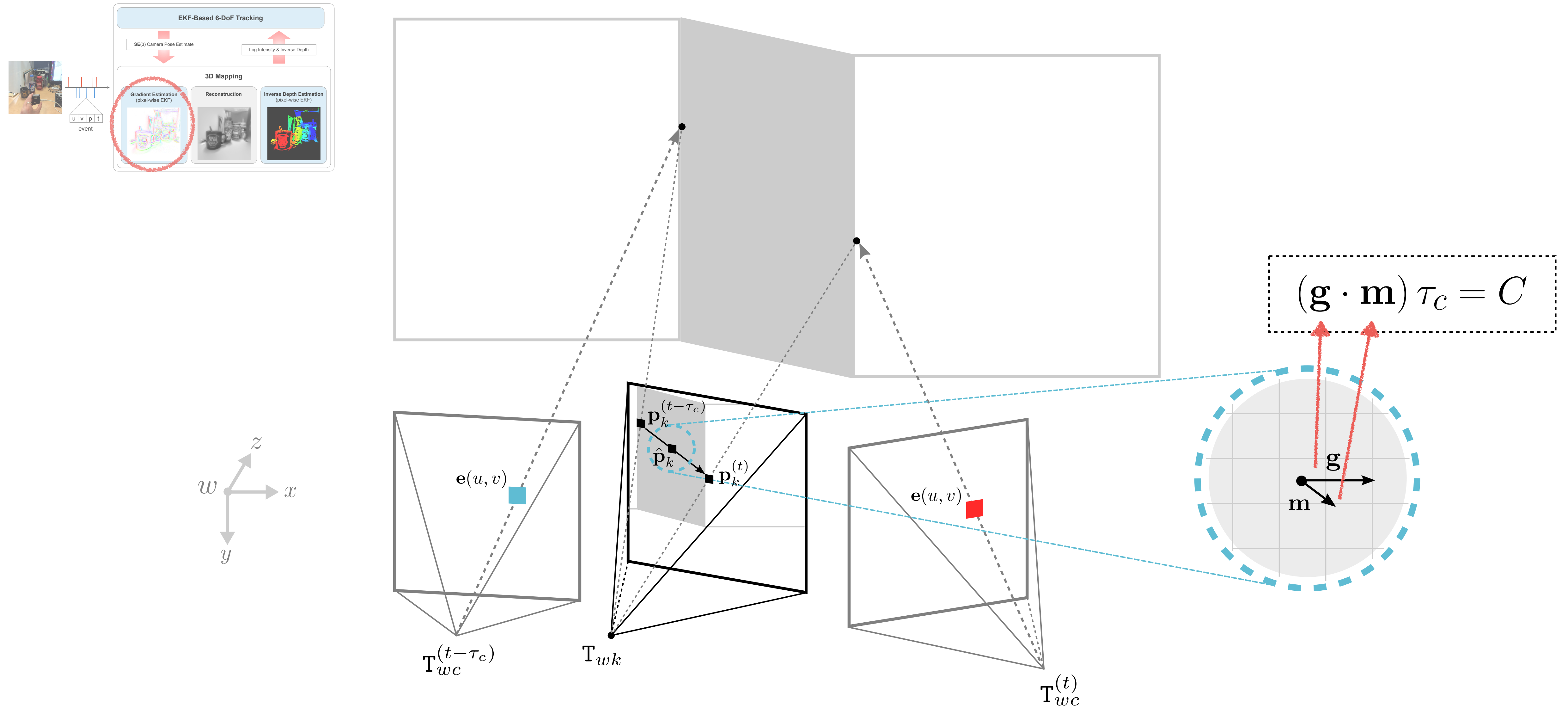


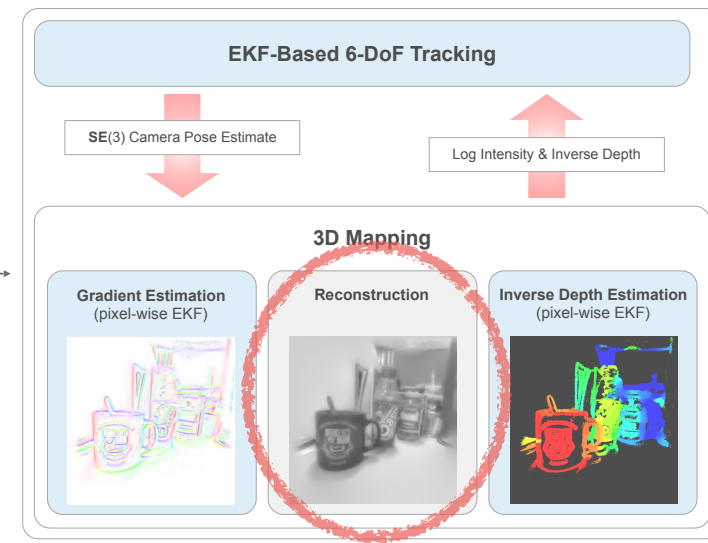




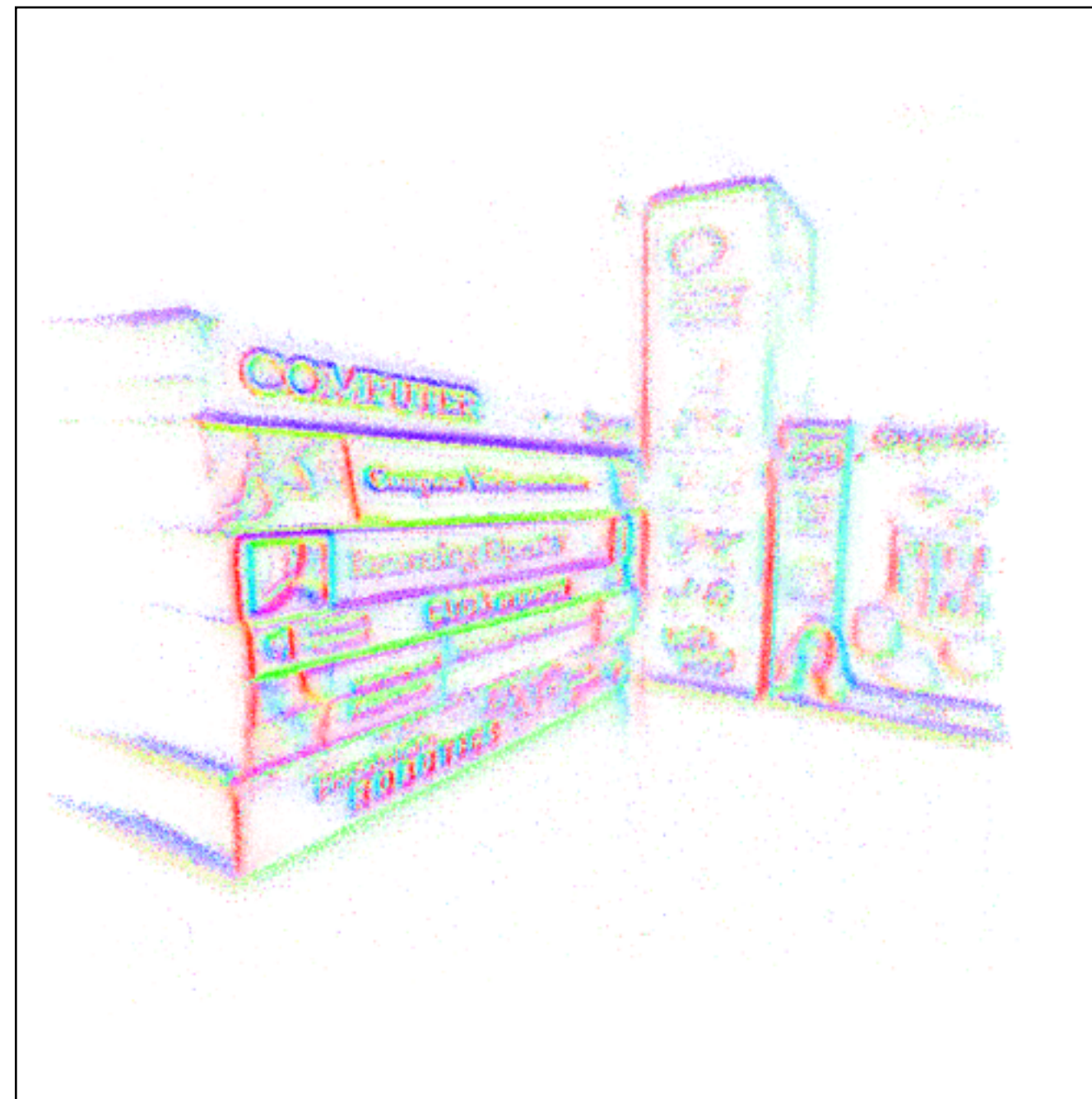


Pixel-Wise EKF Based Gradient Estimation





$$\min_{\mathbf{I}_l} \left\{ \int_{\Omega} \left\| \mathbf{g}(\mathbf{p}_k) - \nabla \mathbf{I}_l(\mathbf{p}_k) \right\|_{\epsilon_d}^h + \lambda \left\| \nabla \mathbf{I}_l(\mathbf{p}_k) \right\|_{\epsilon_r}^h d\mathbf{p}_k \right\}$$

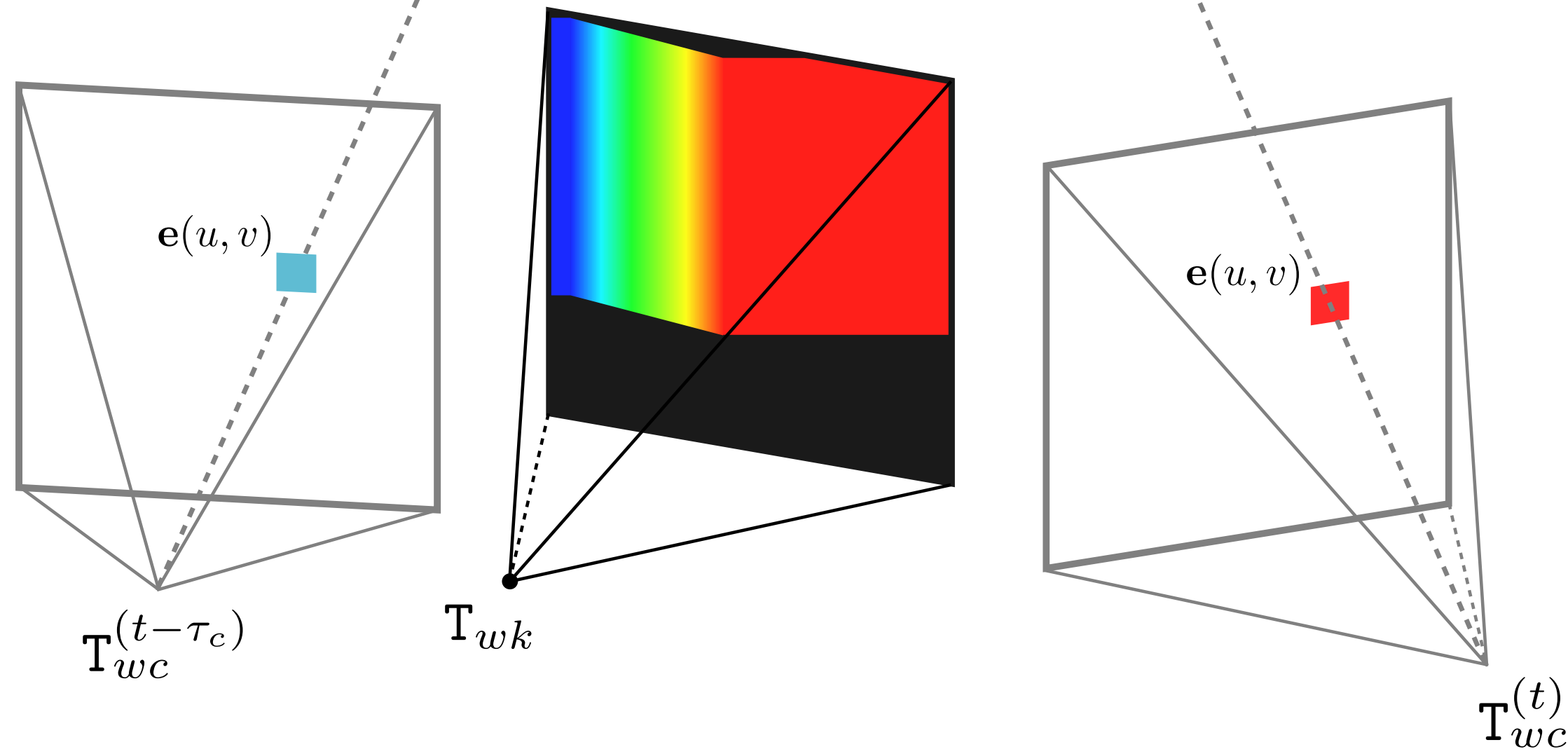
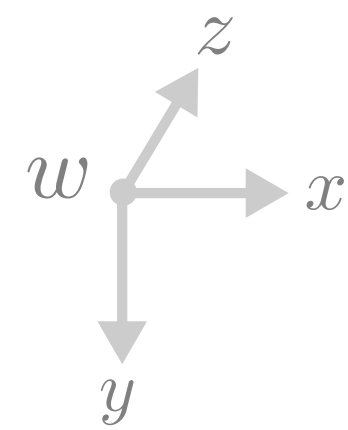
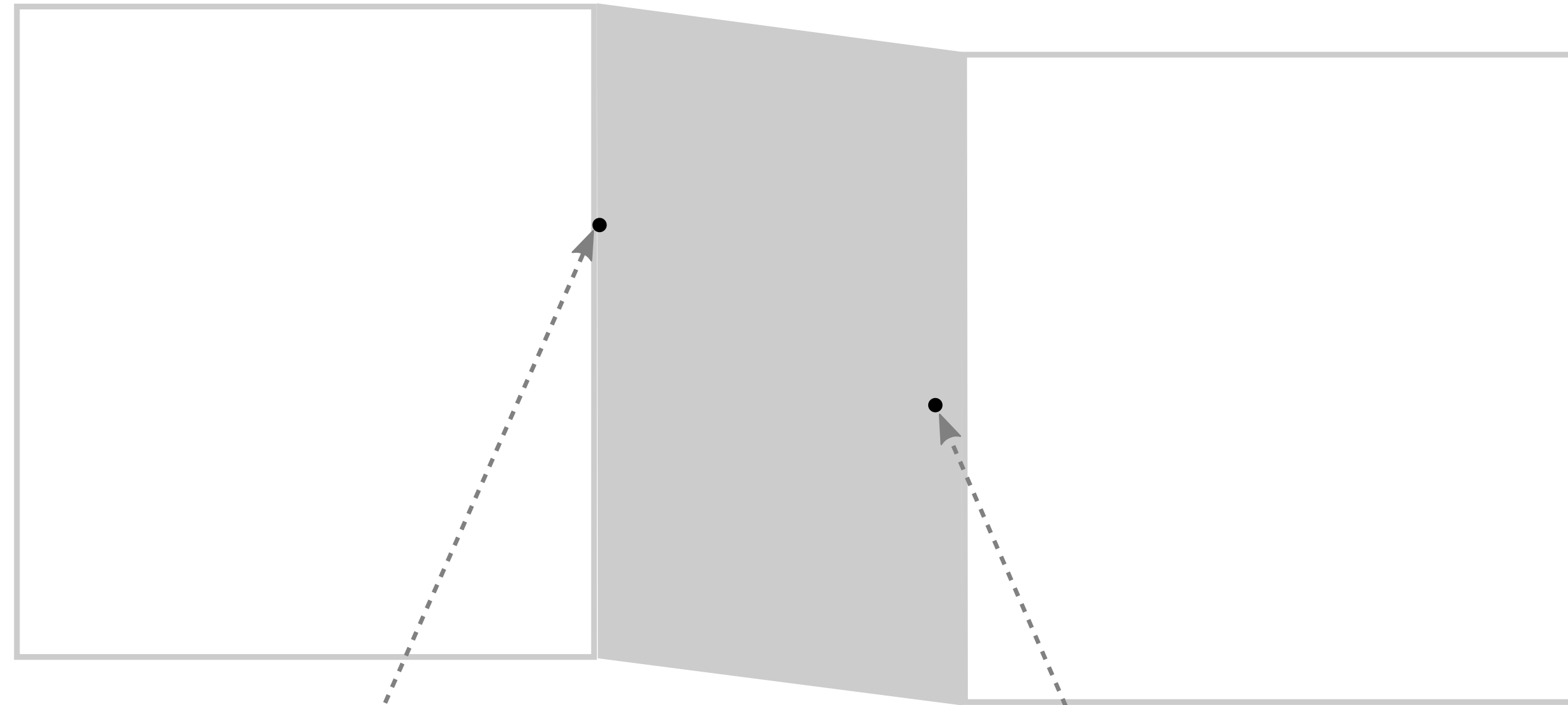
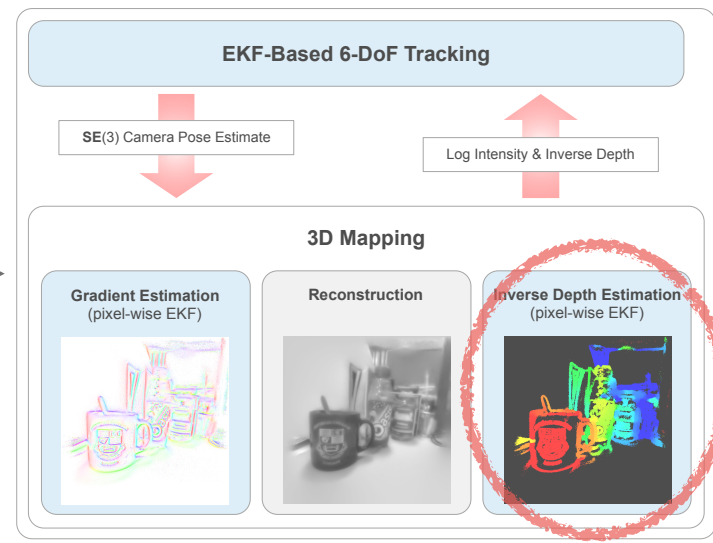


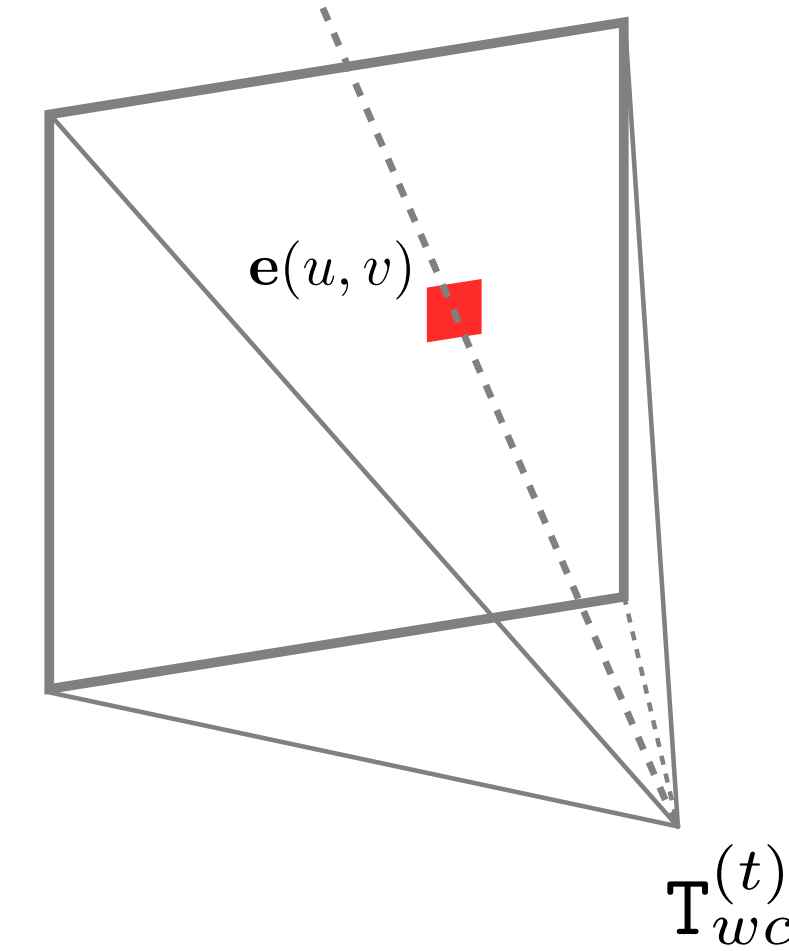
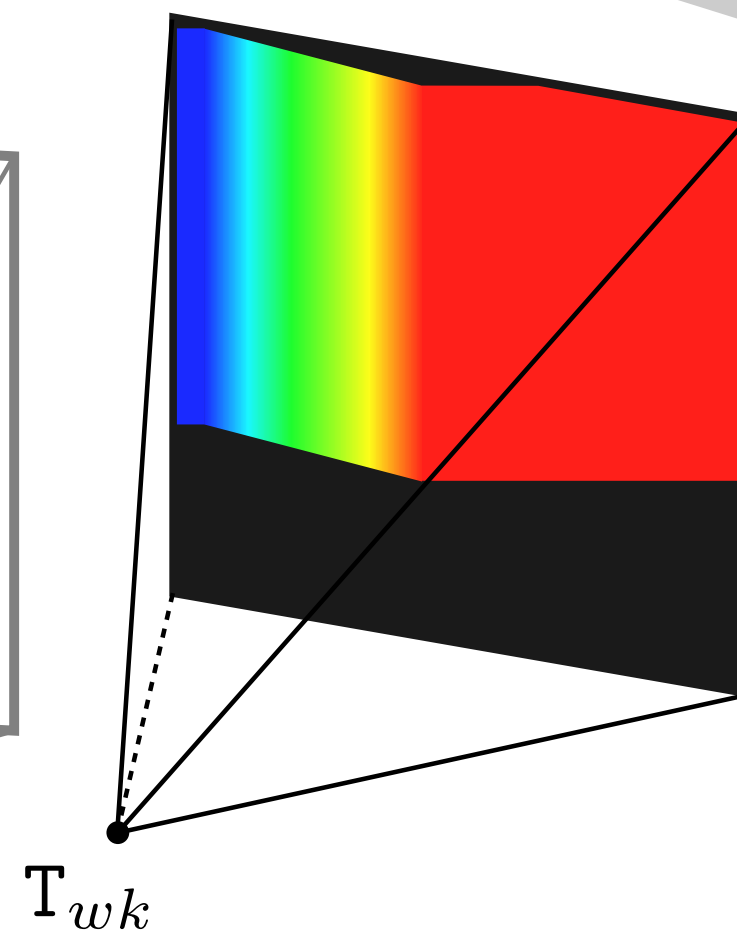
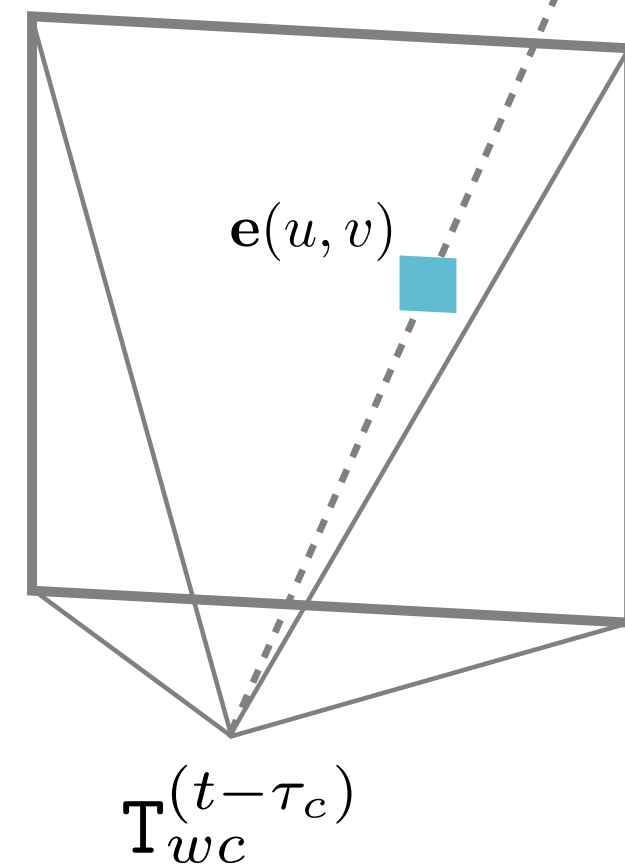
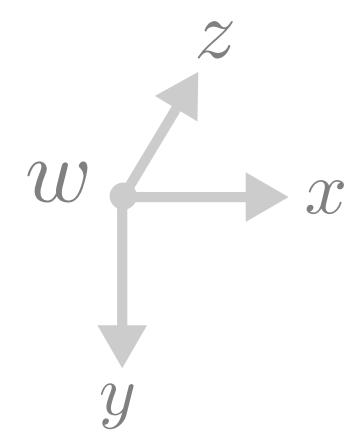
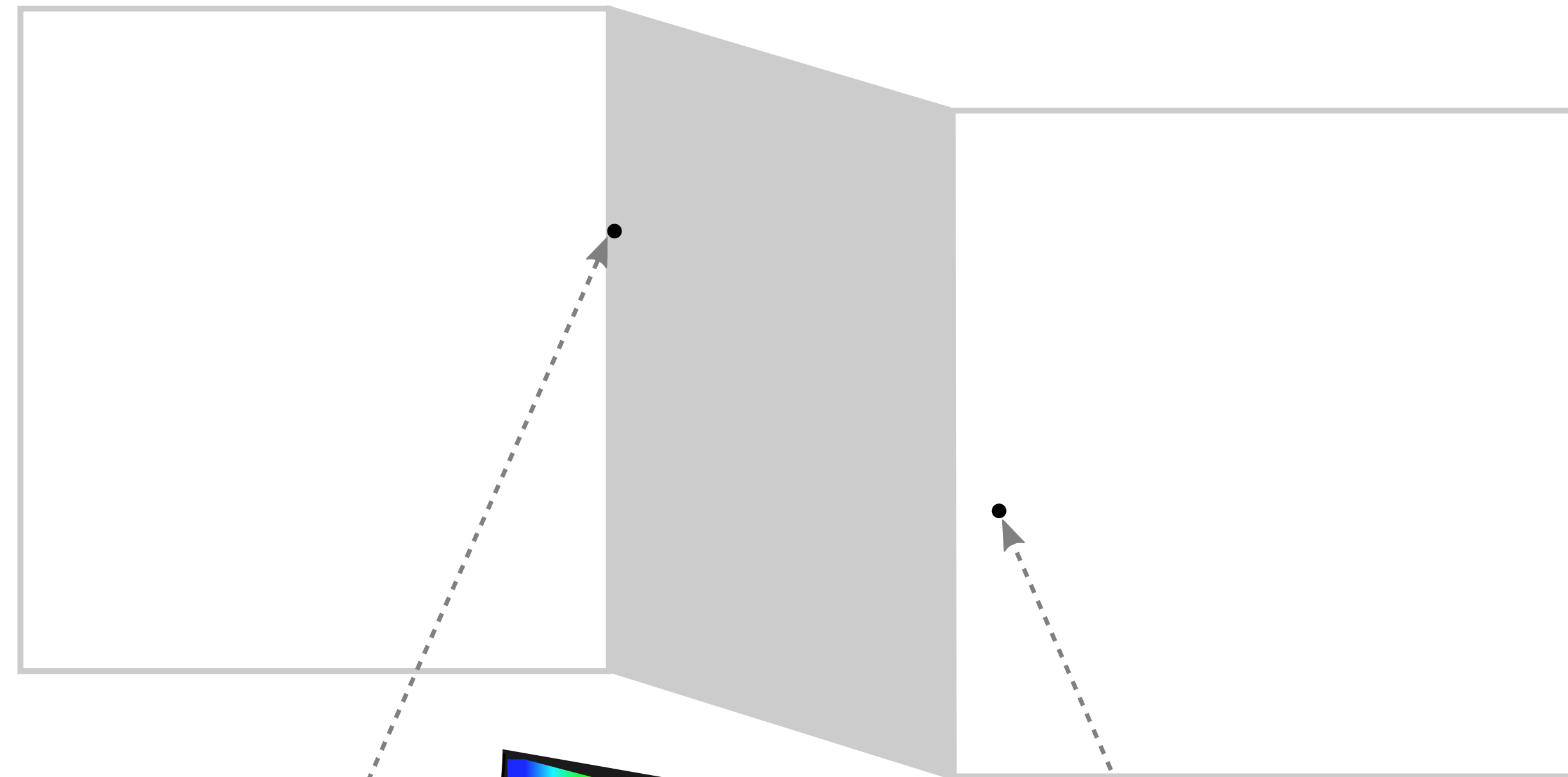
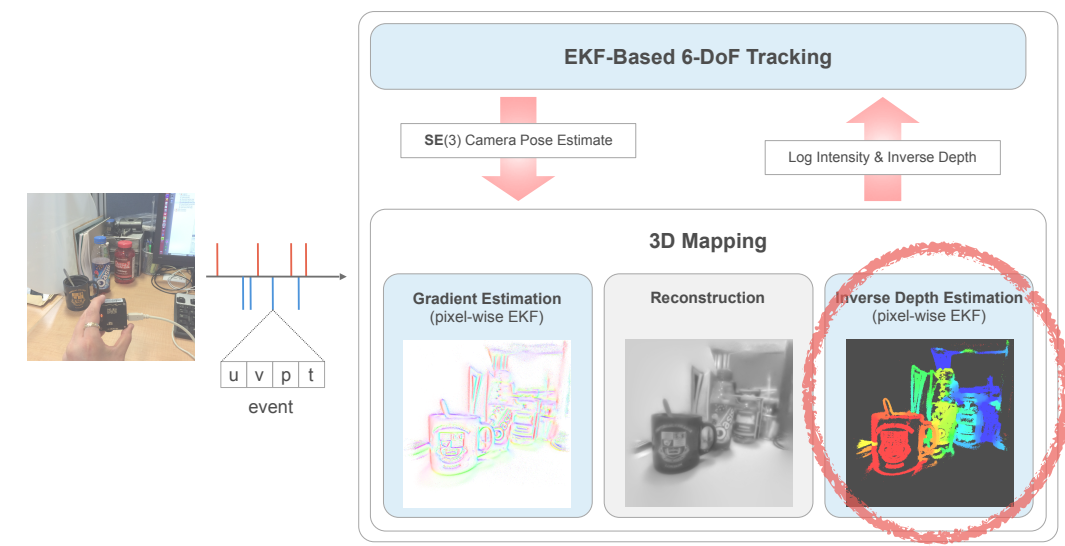
gradient estimation

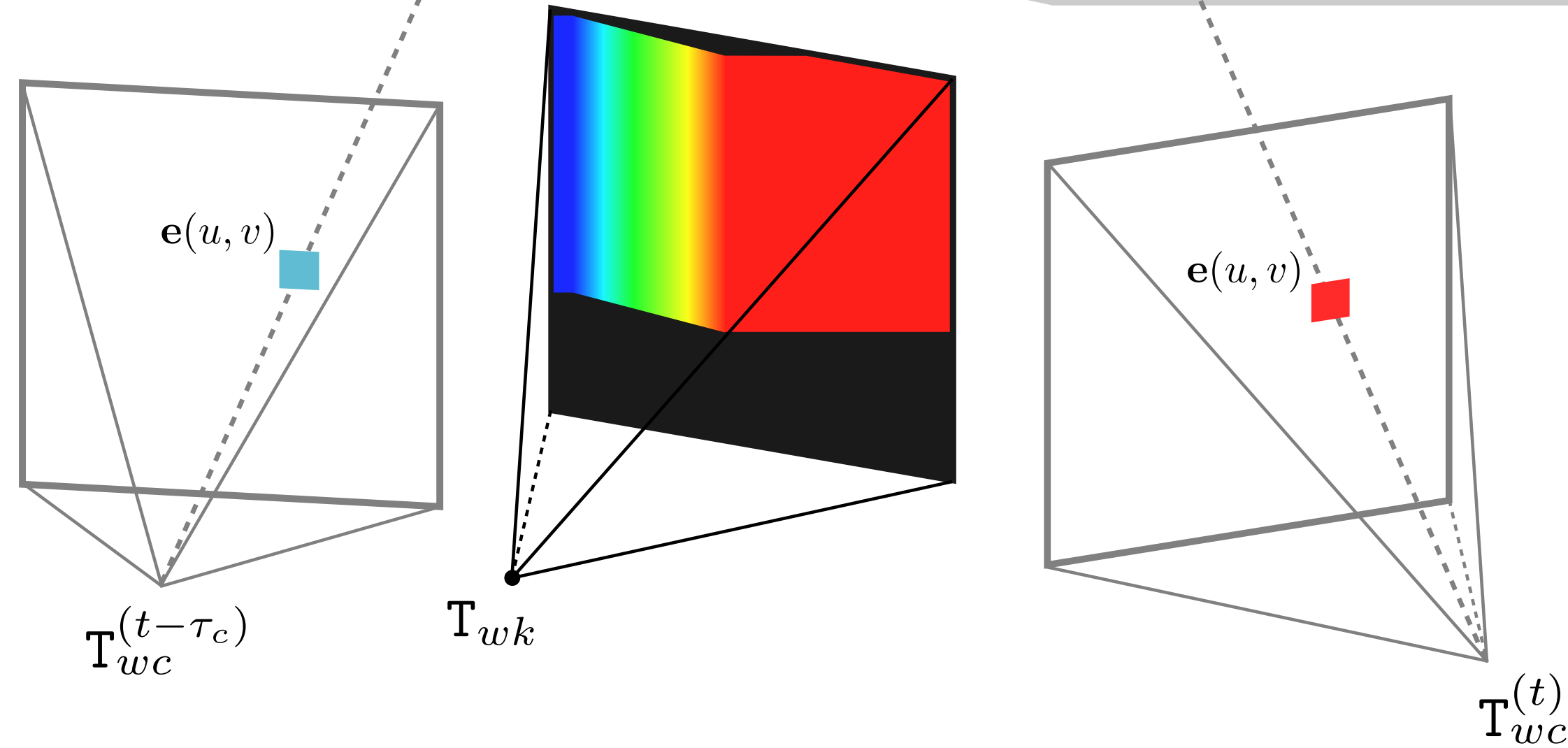
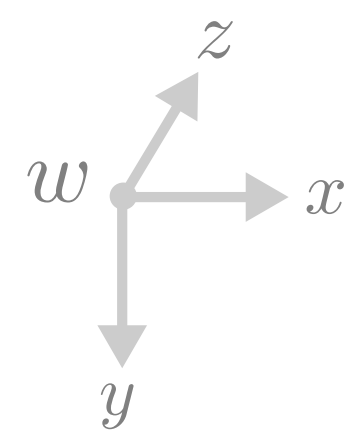
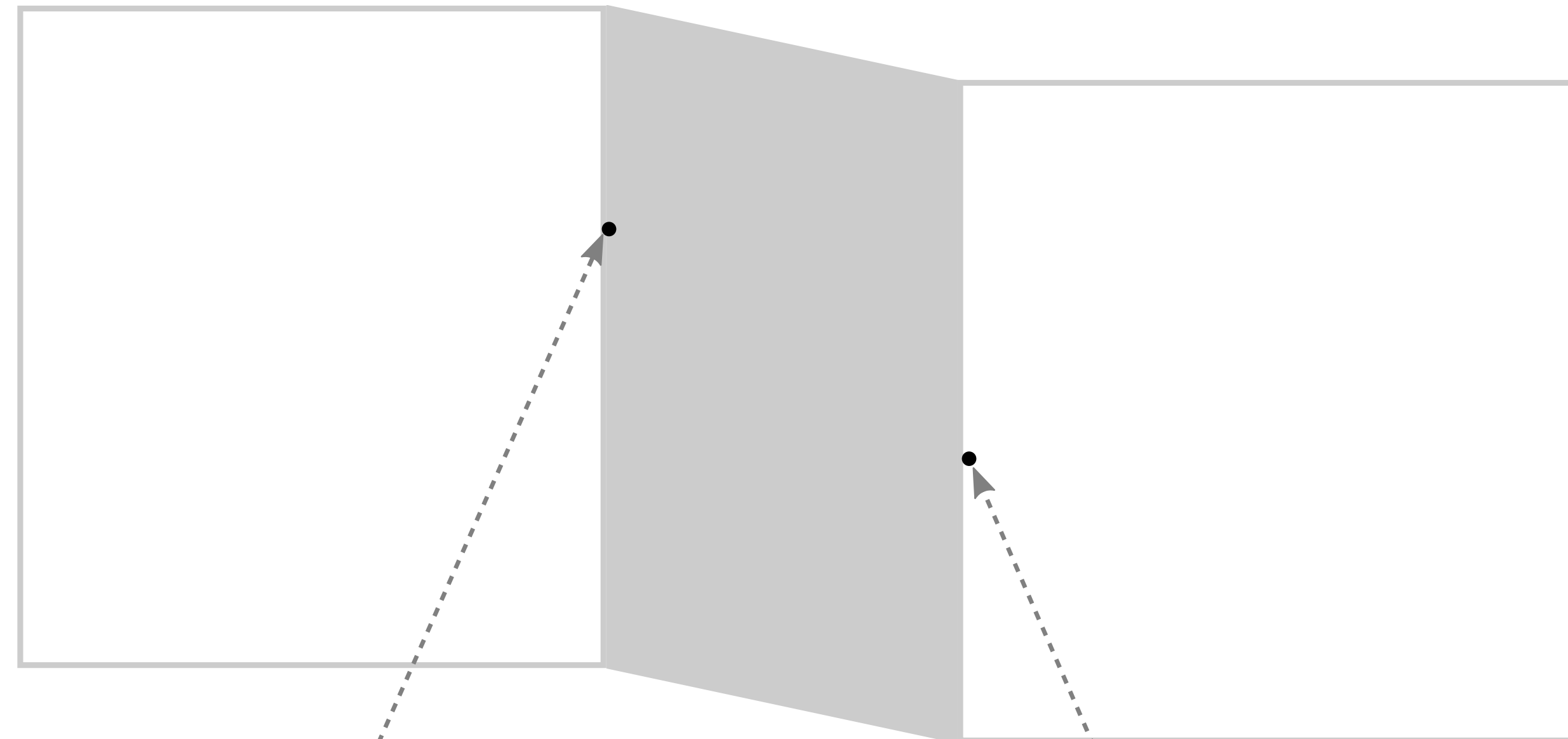
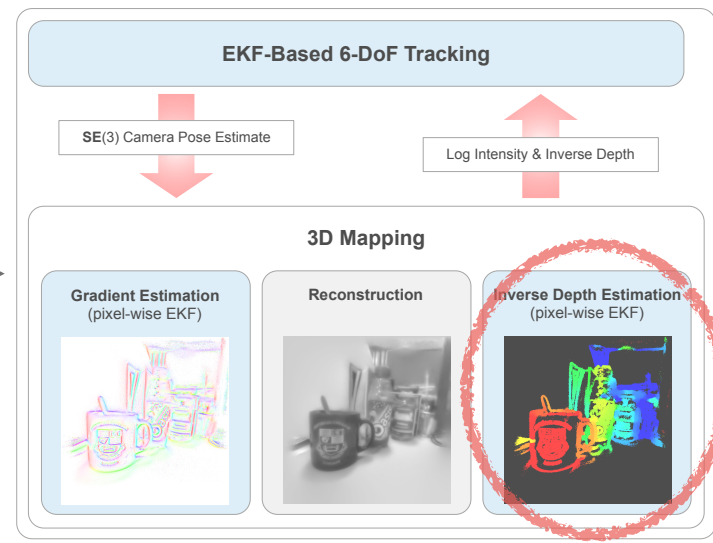


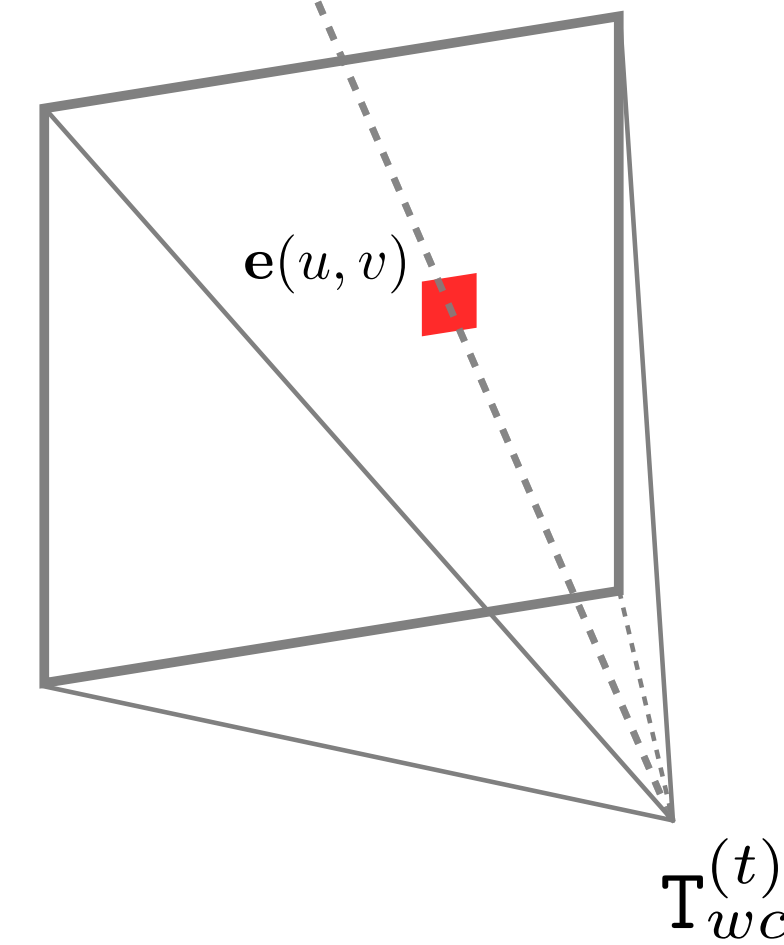
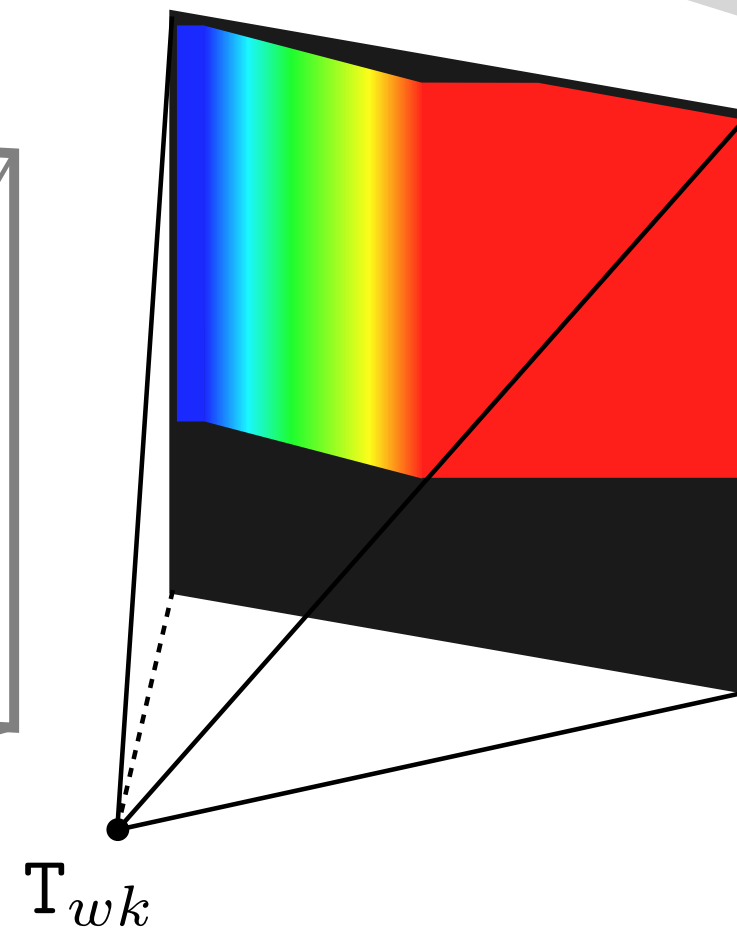
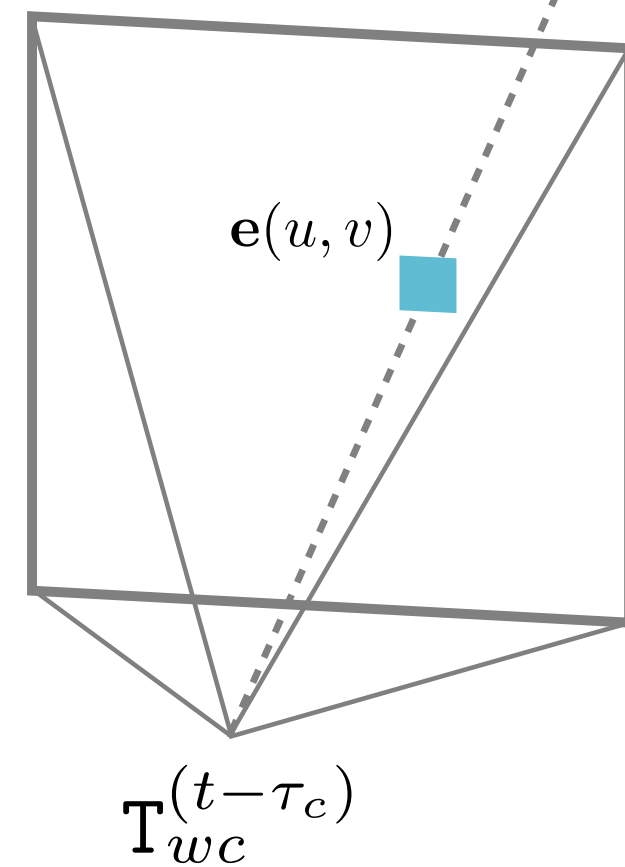
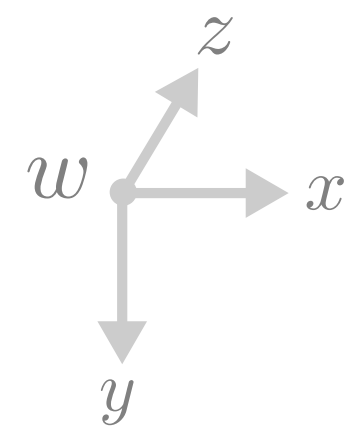
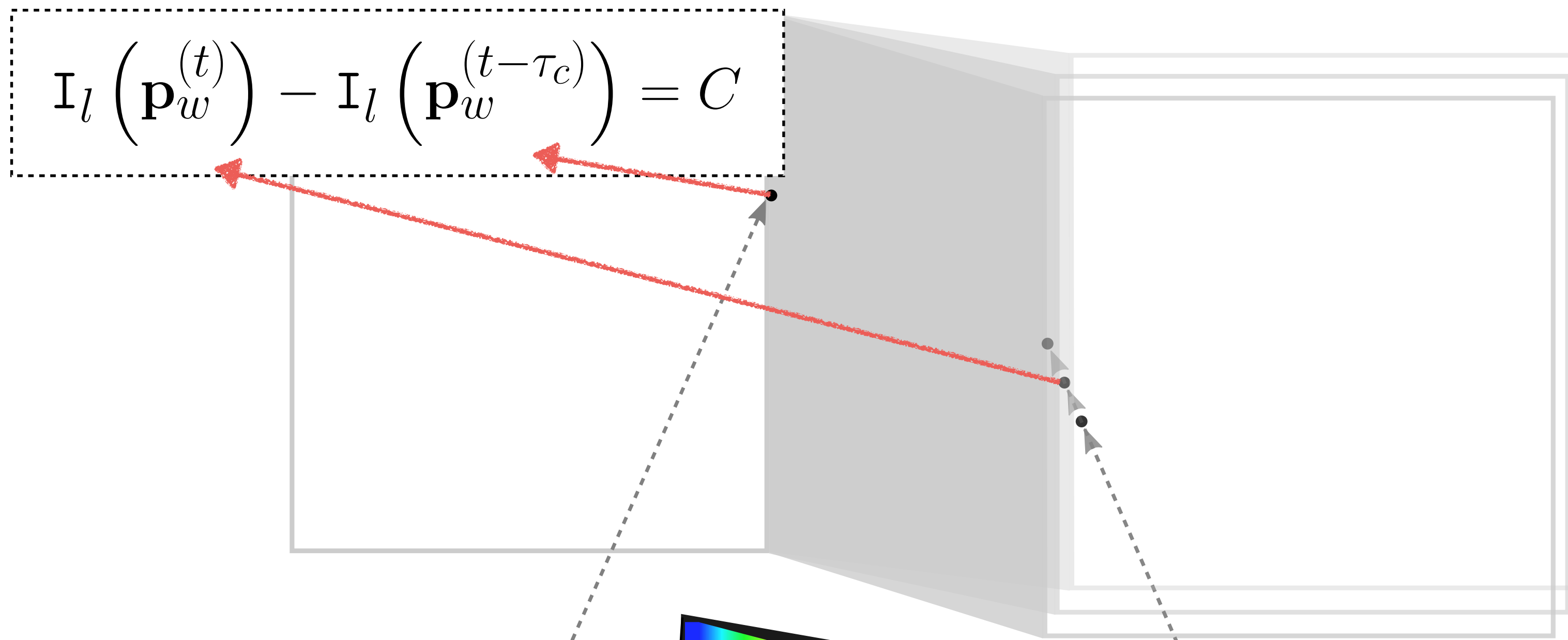
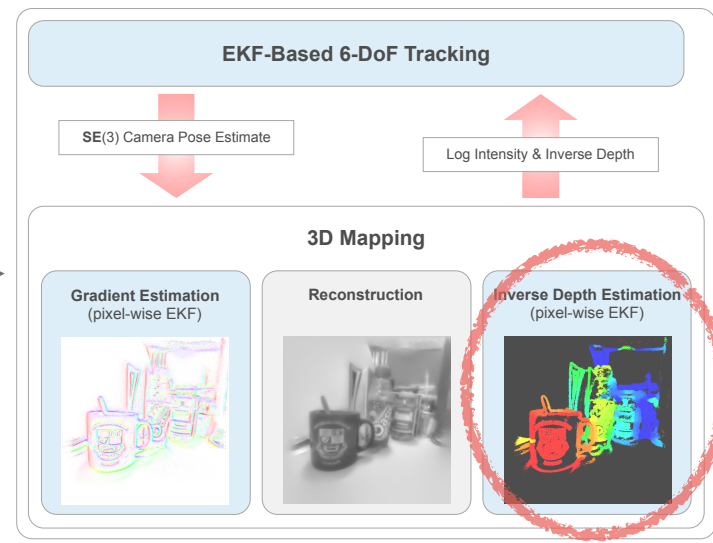
intensity reconstruction

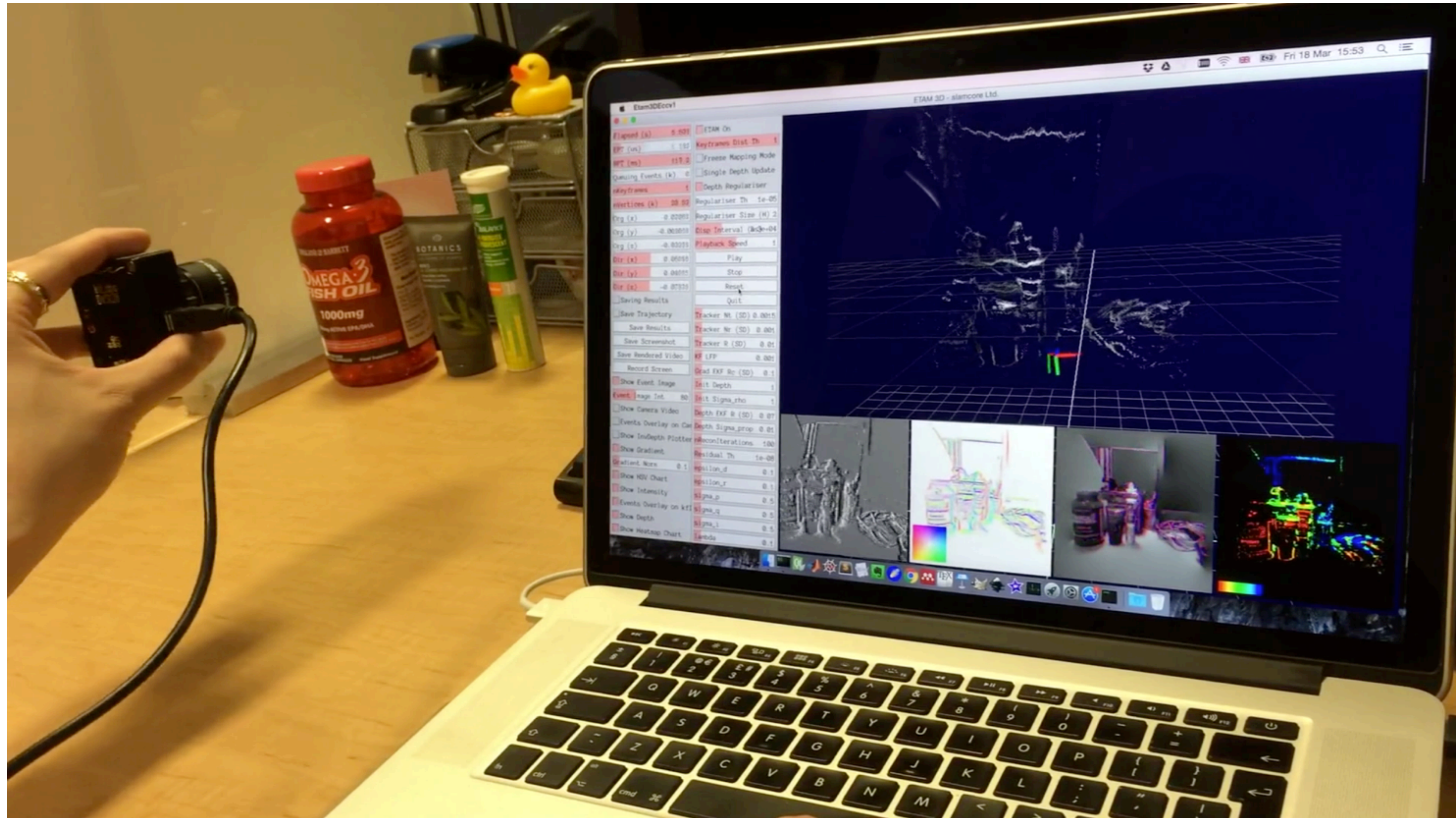




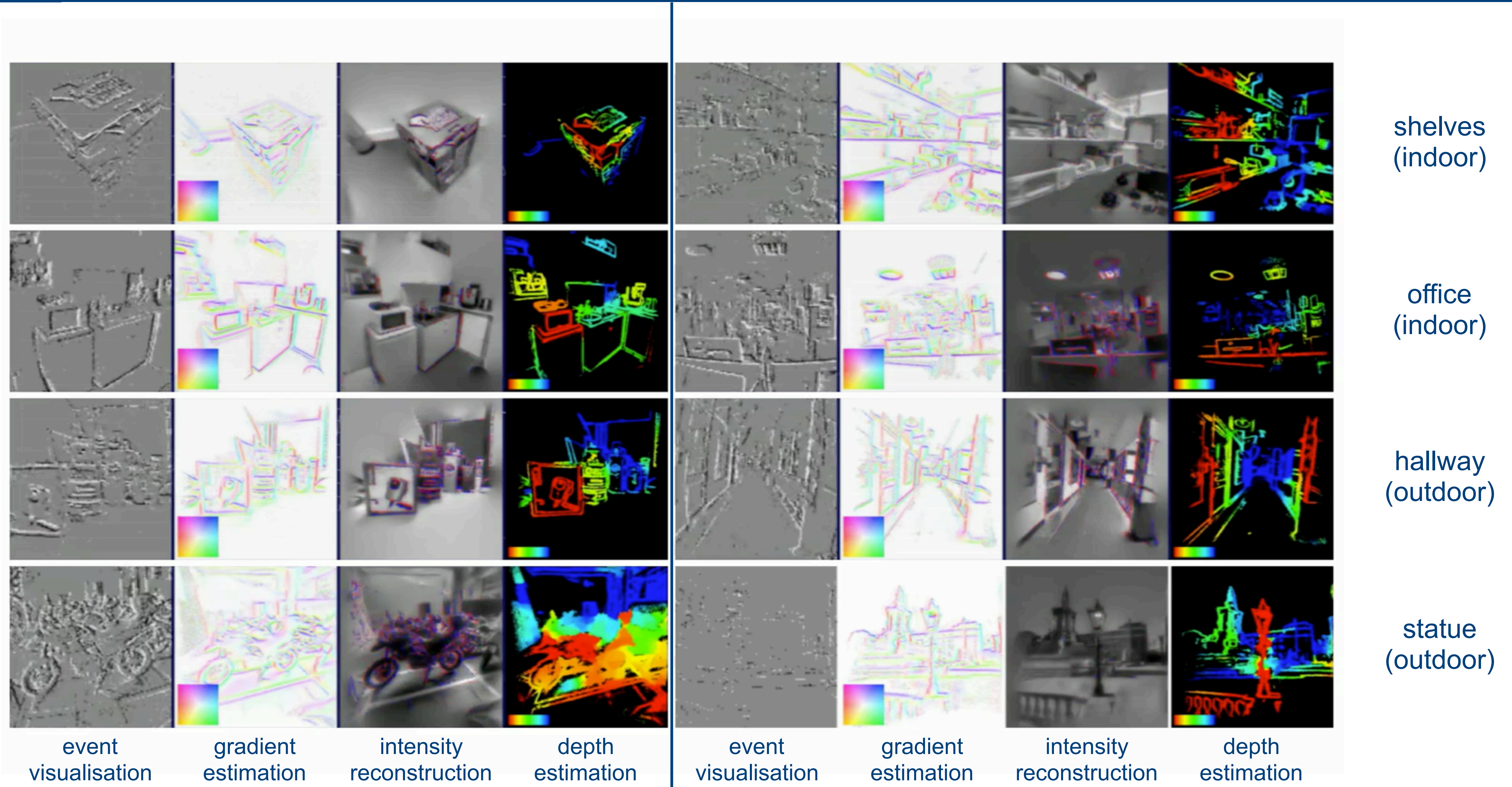




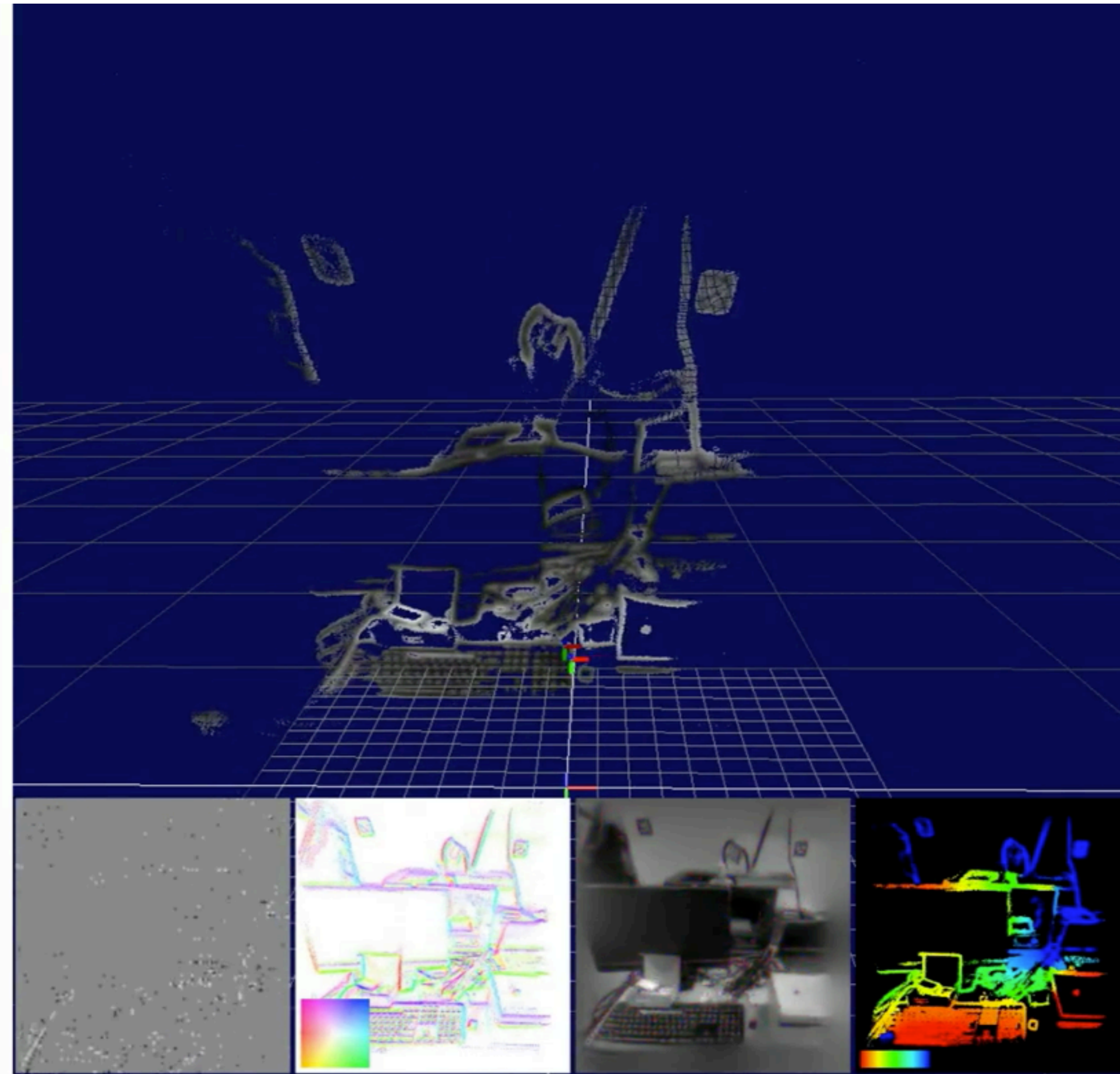




Results: Single Keyframe Estimation



Results: Multiple Keyframes



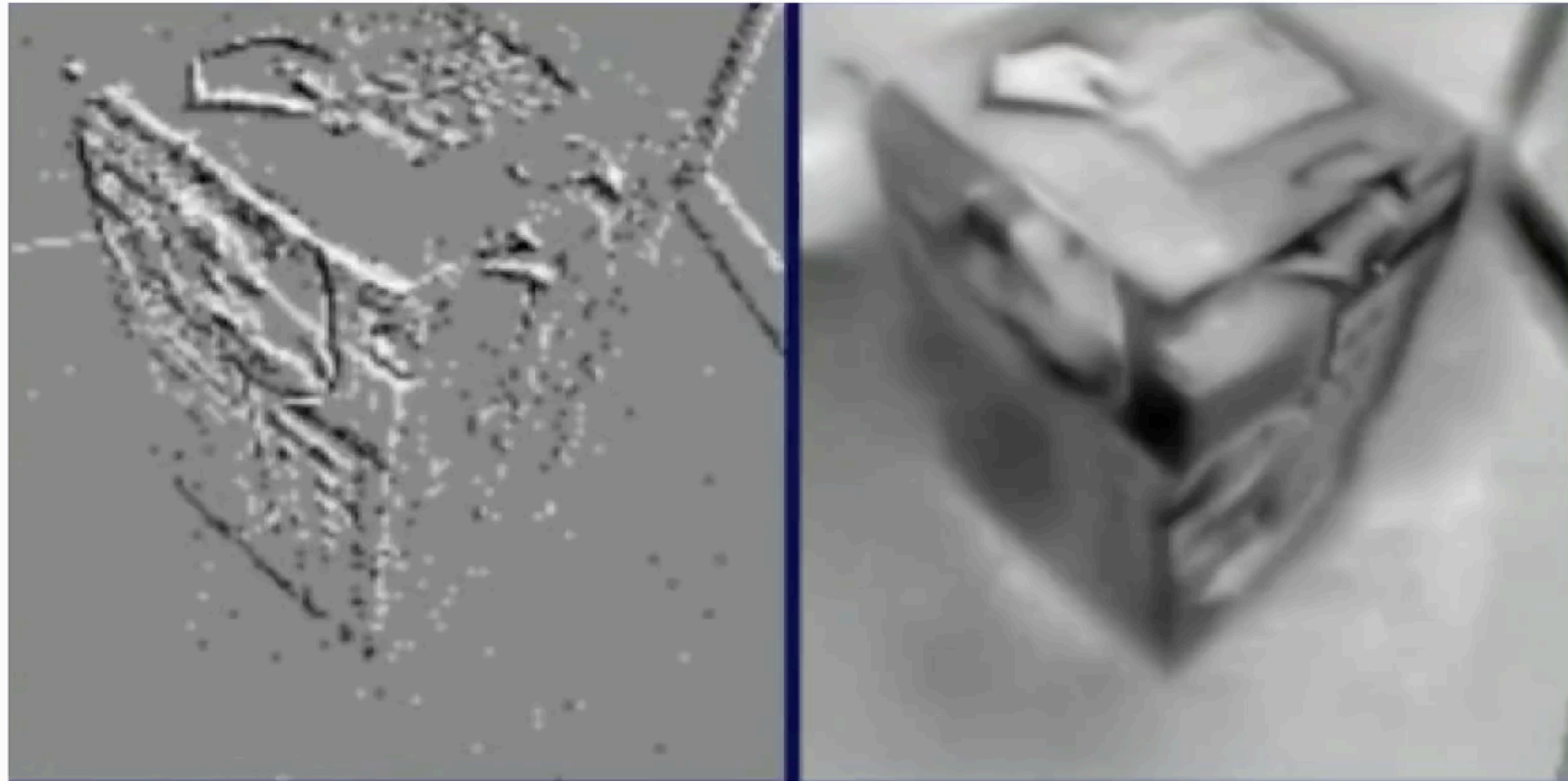
event
visualisation

gradient
estimation

intensity
reconstruction

depth
estimation





event visualisation

rendered video

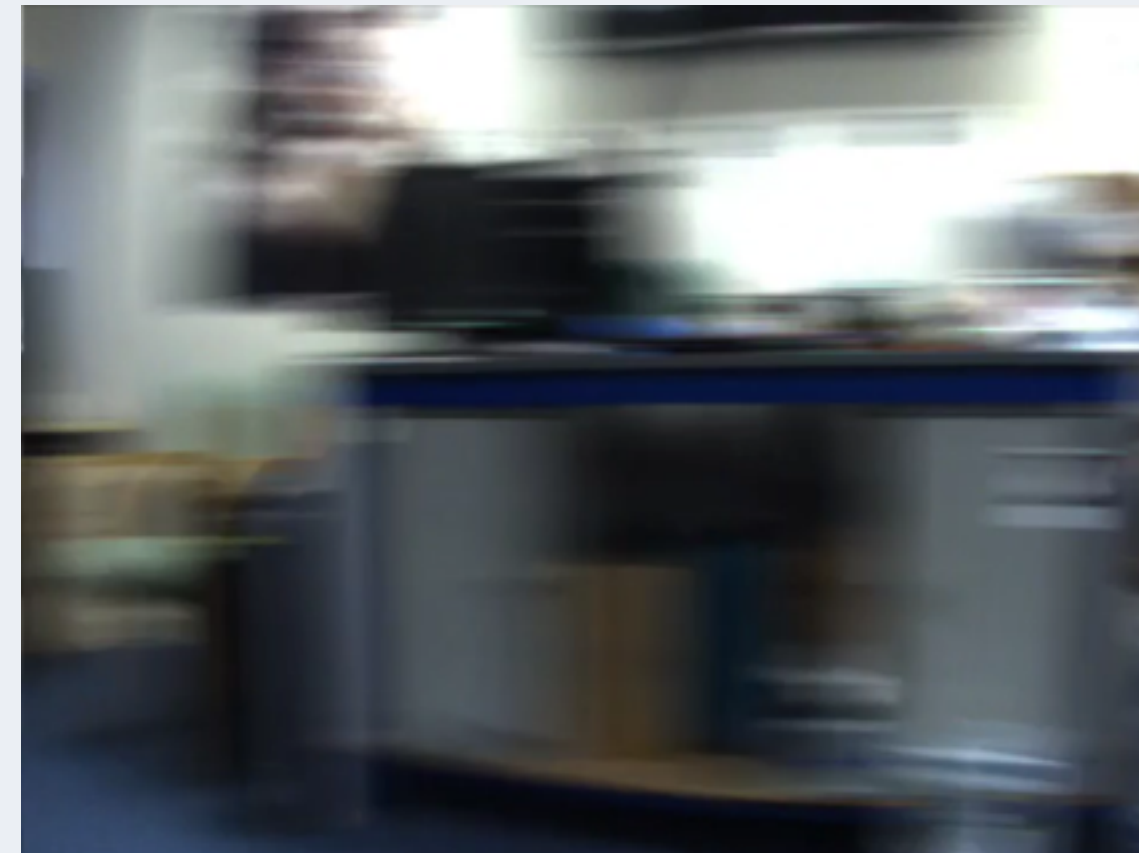


- the first 6-DoF tracking and 3D reconstruction method purely based on a stream of events with no additional sensing
- runs in real-time on a standard PC
- hope this opens up the door to practical solutions to the current limitations of real-world SLAM applications

fast motion tracking comparison

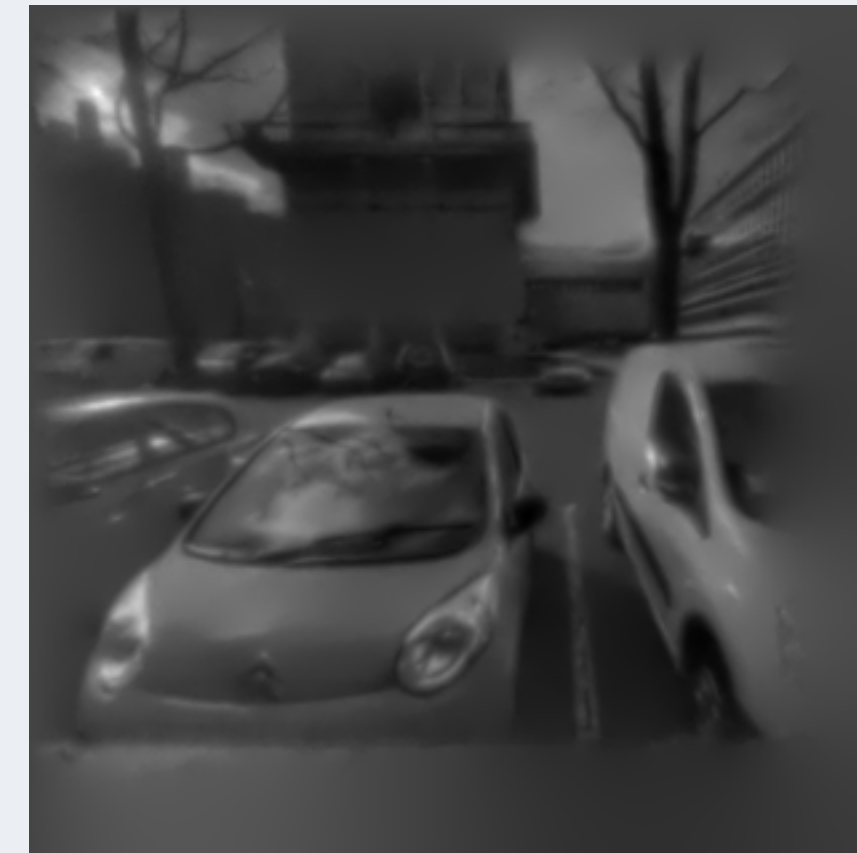


our method



standard camera

dynamic range comparison



our method



standard camera

Thank you for your attention!

For more about our work, please come to our poster session
(O-4A-01, 11:00 - 12:30).

