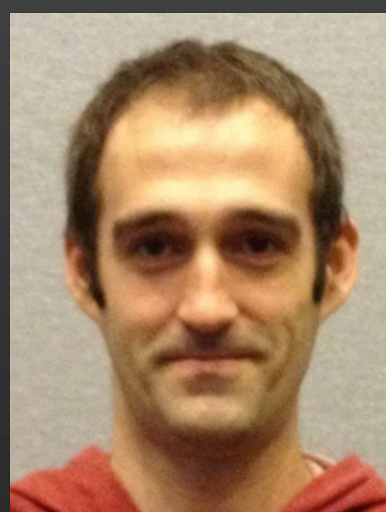
Bayesian View Synthesis and Image-Based Rendering Principles



Sergi Pujades[1], Frédéric Devernay[1], Bastian Goldluecke[2]

CVPR 2014

[1] informatics mathematics

[2] University of Konstanz

Image Based Rendering

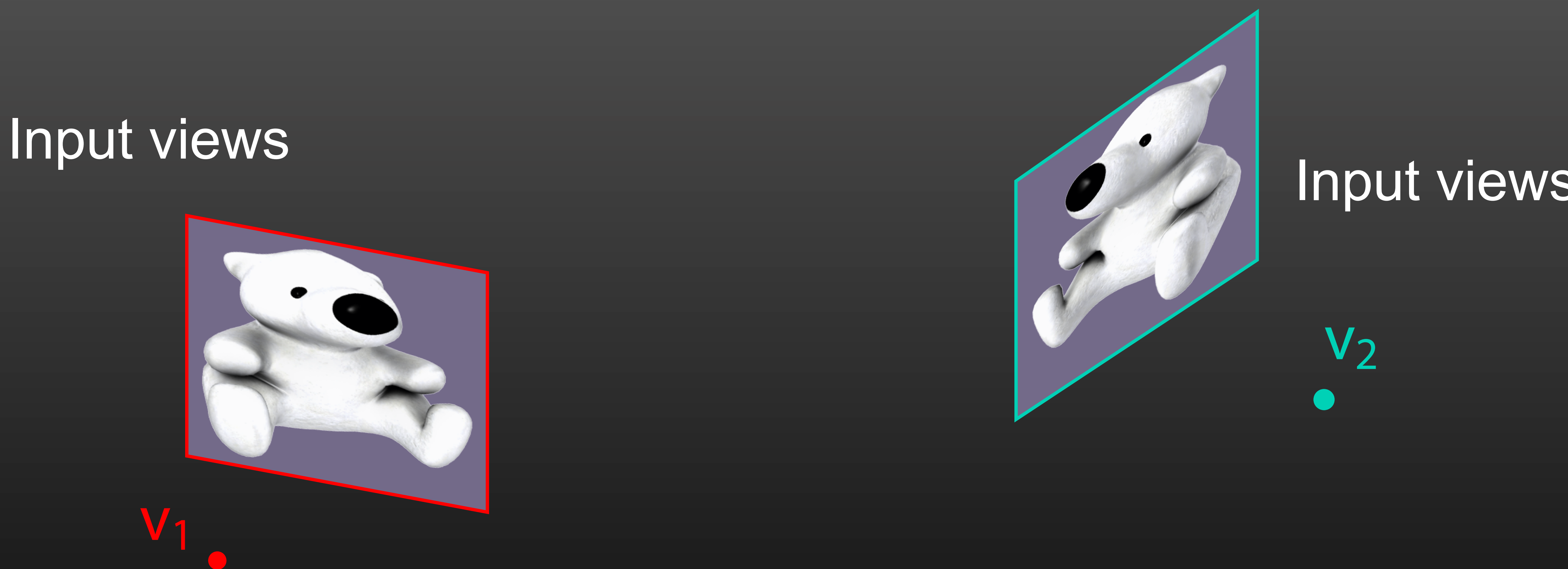


Image Based Rendering

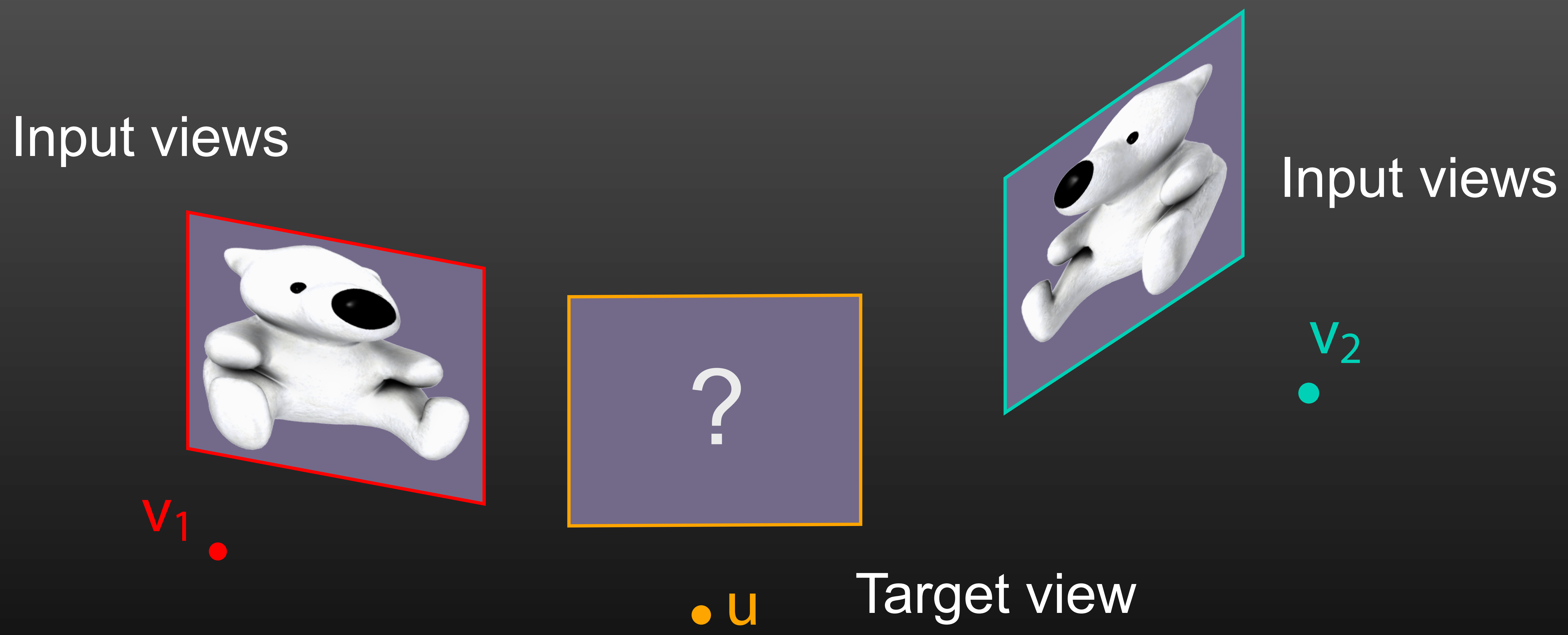


Image Based Rendering

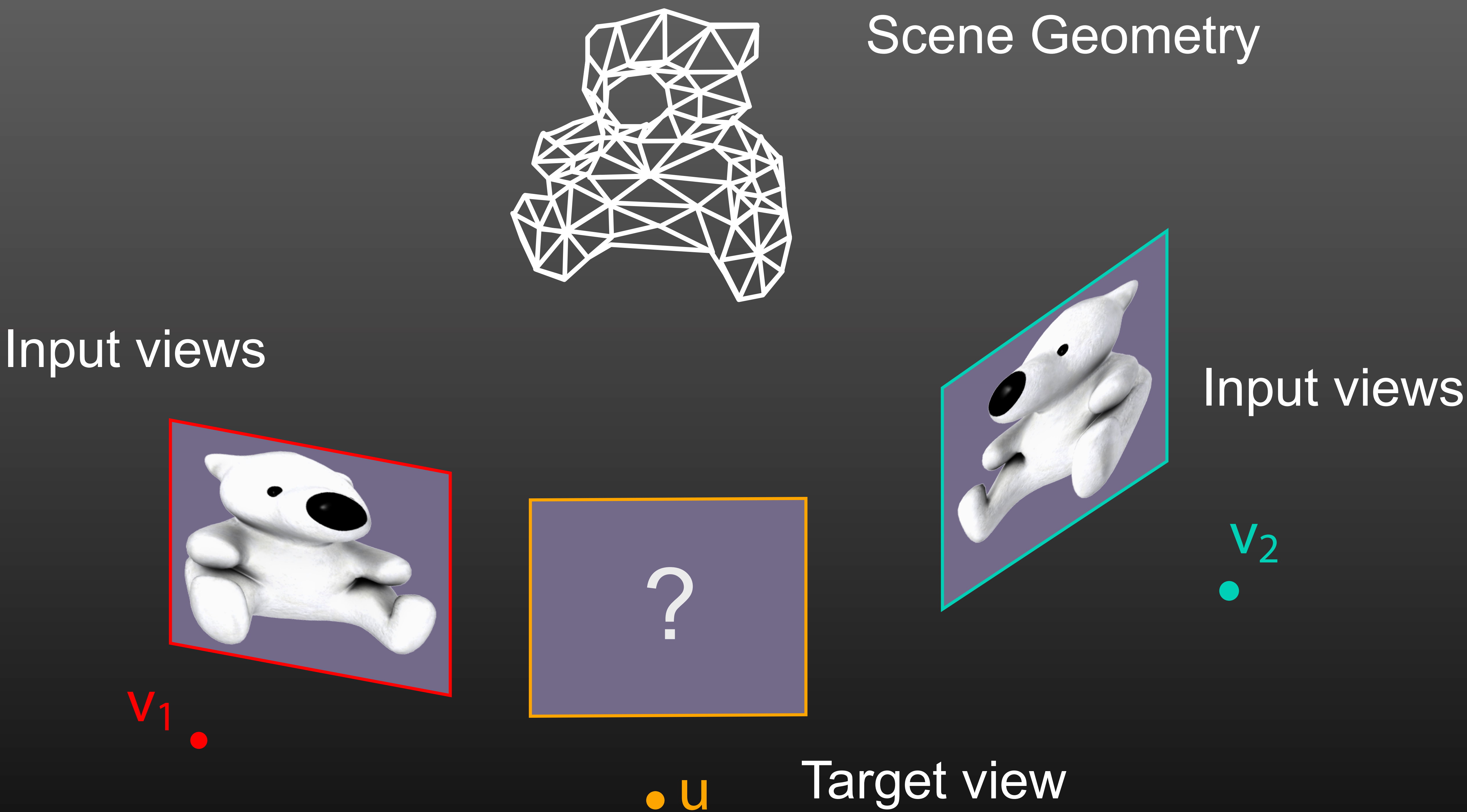
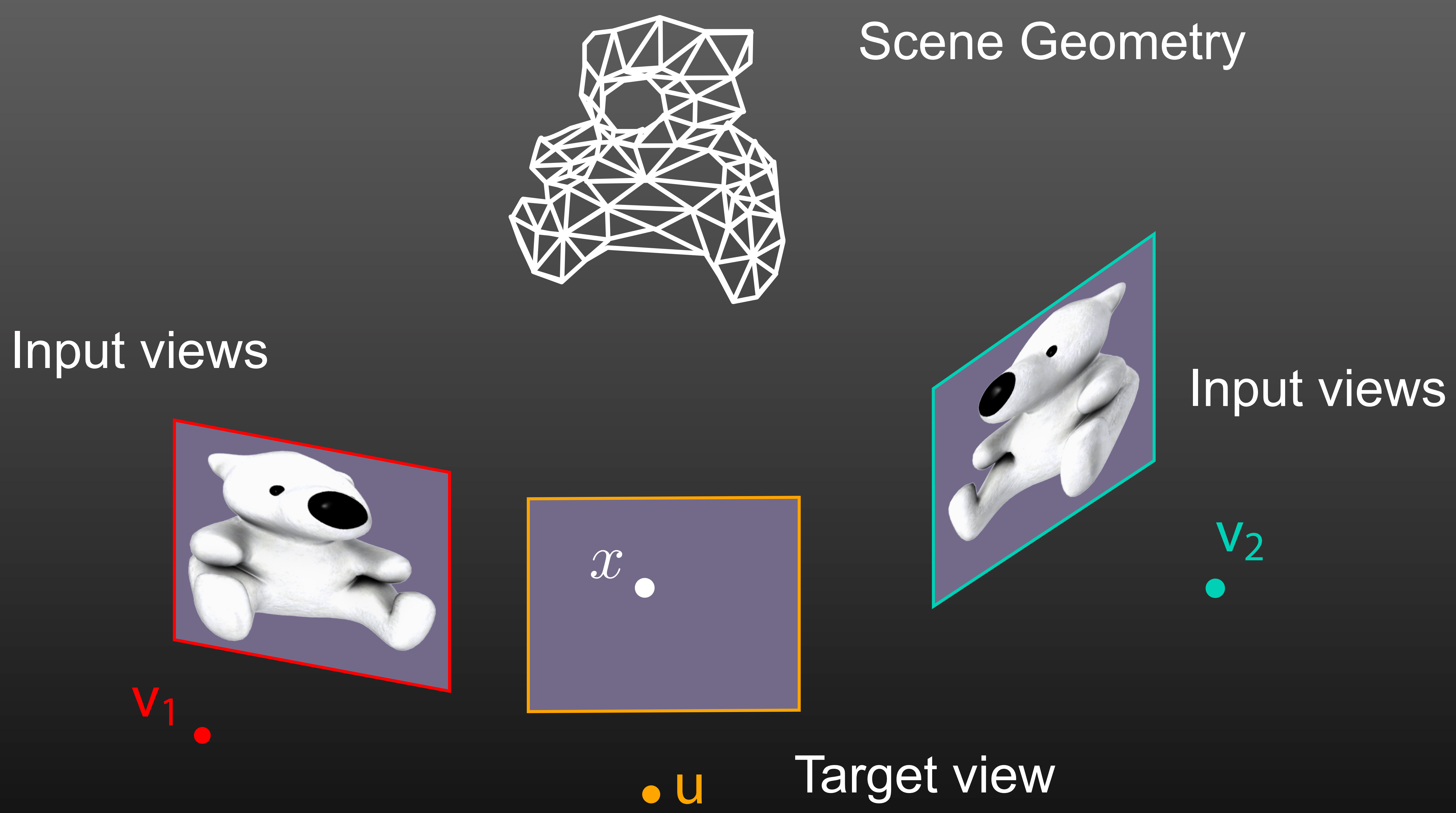


Image Based Rendering



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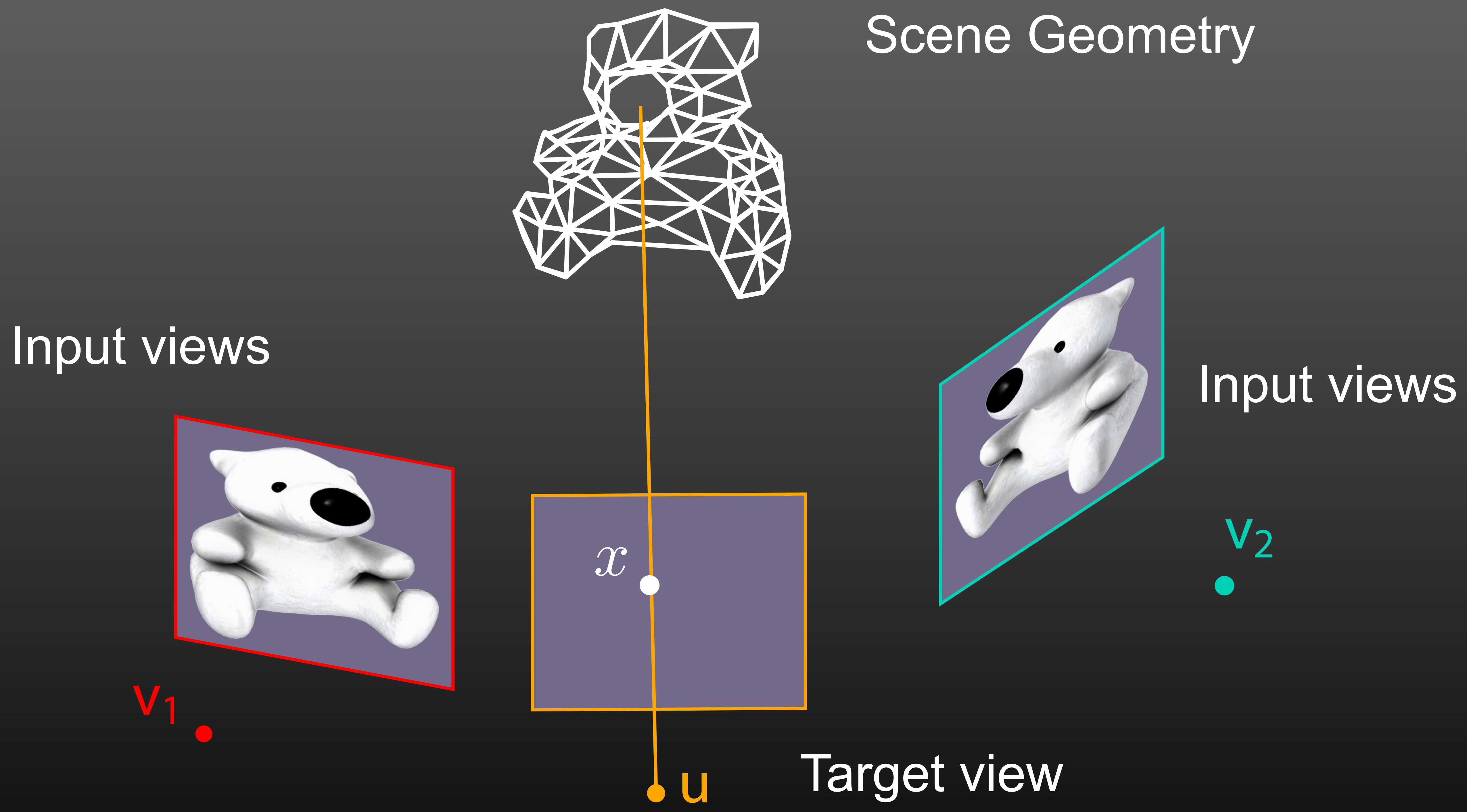

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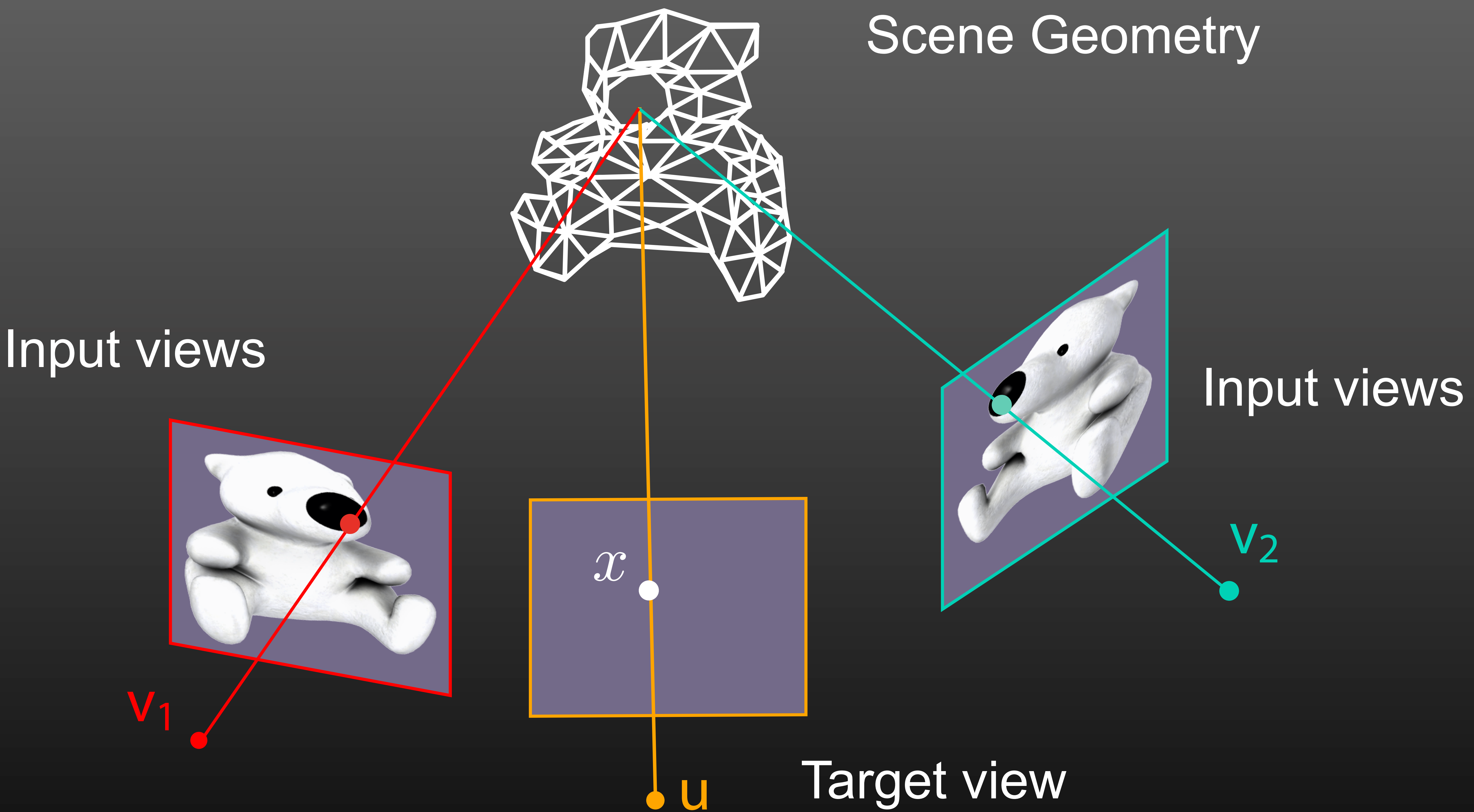
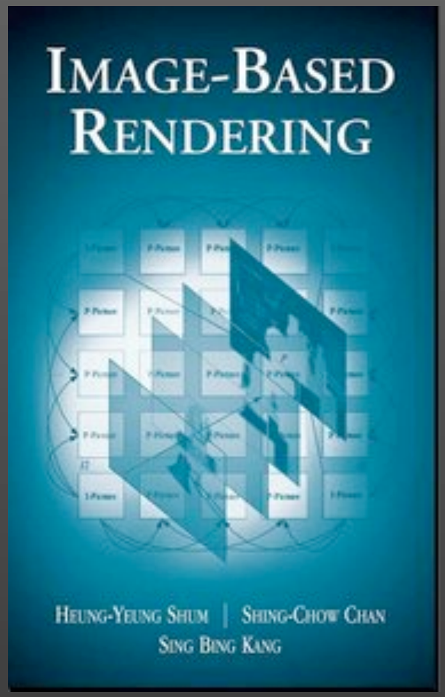


State of the art



IBR Continum

Scene Geometry

less → **more**

Light field — Lumigraph — Texture-mapped models

State of the art

Unstructured Lumigraph Rendering
C. Buehler et al. - SIGGRAPH 2001

8 Desirable Properties

- Use of geometric proxies
- Unstructured input
- Minimal angular deviation
  - Epipole consistency
  - Equivalent ray consistency
- Resolution sensitivity
- Continuity
- Real-time

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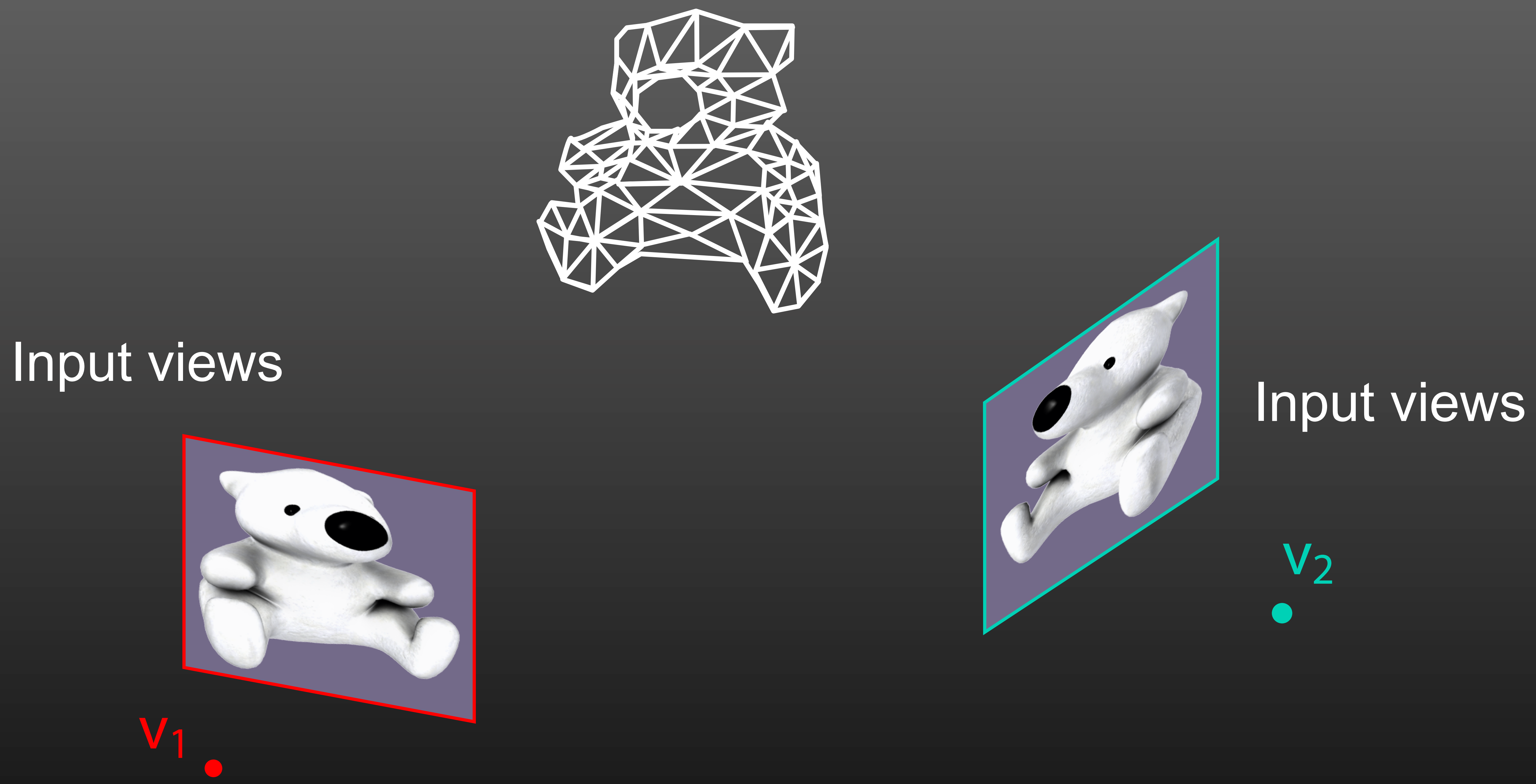
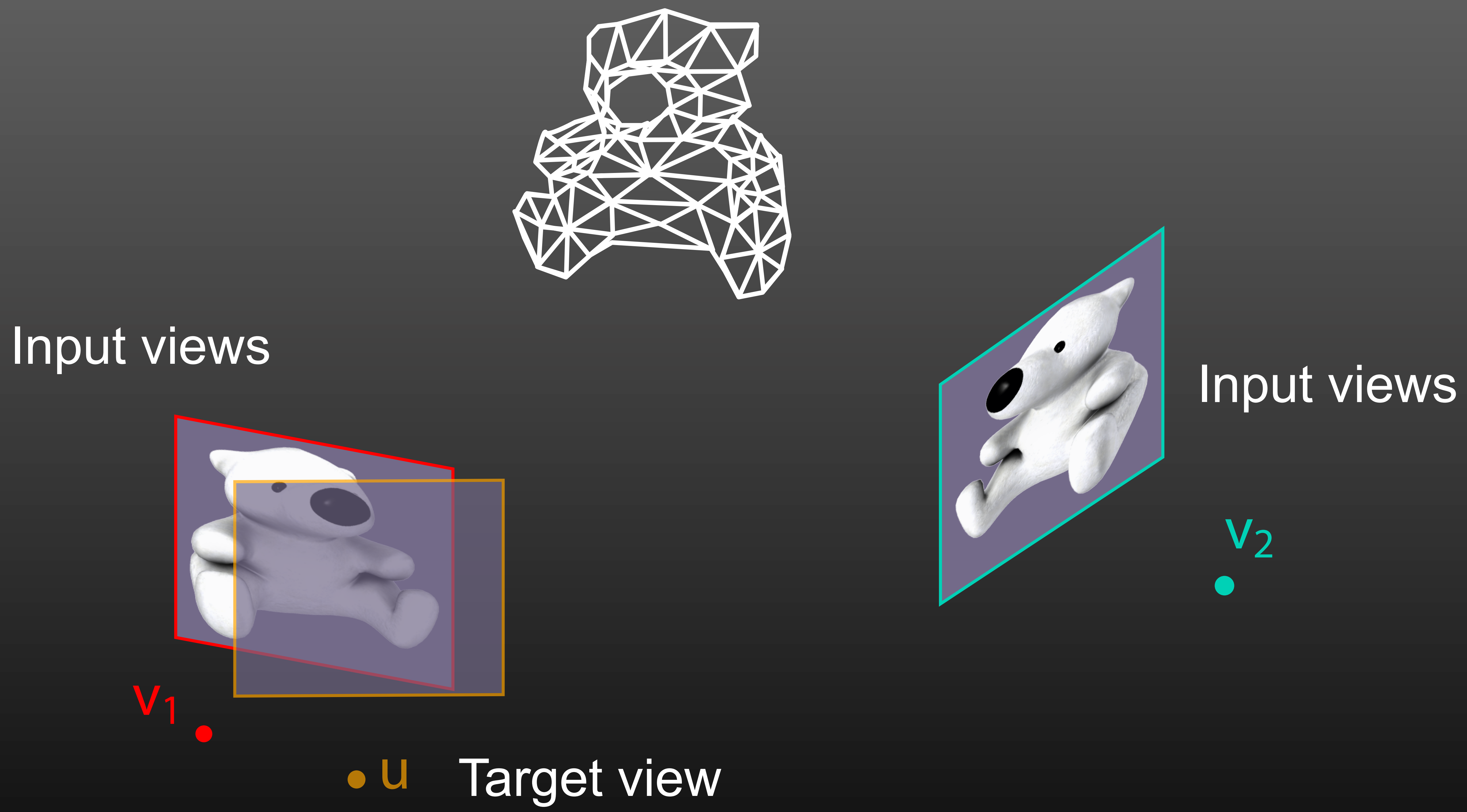
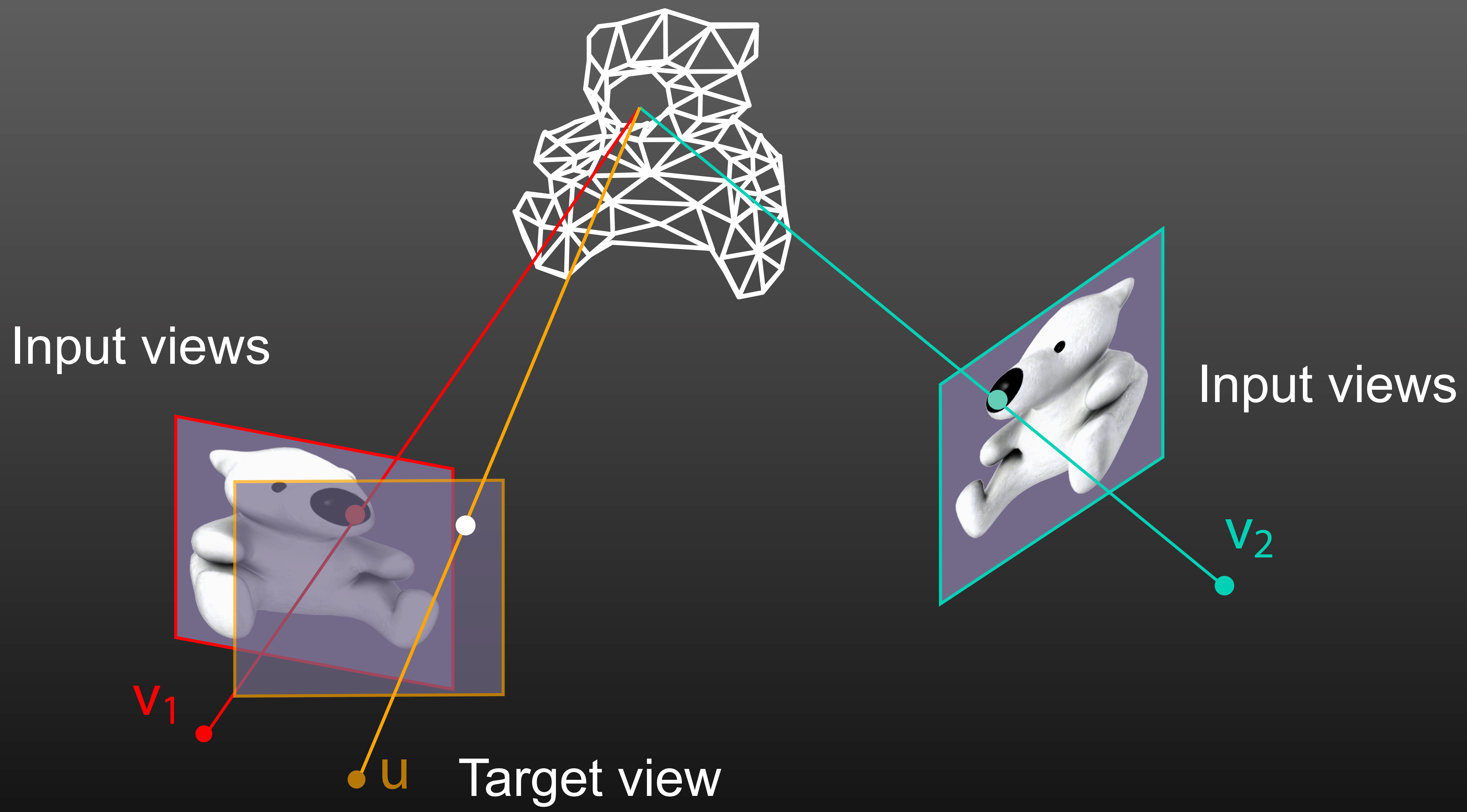
Minimal angular deviation



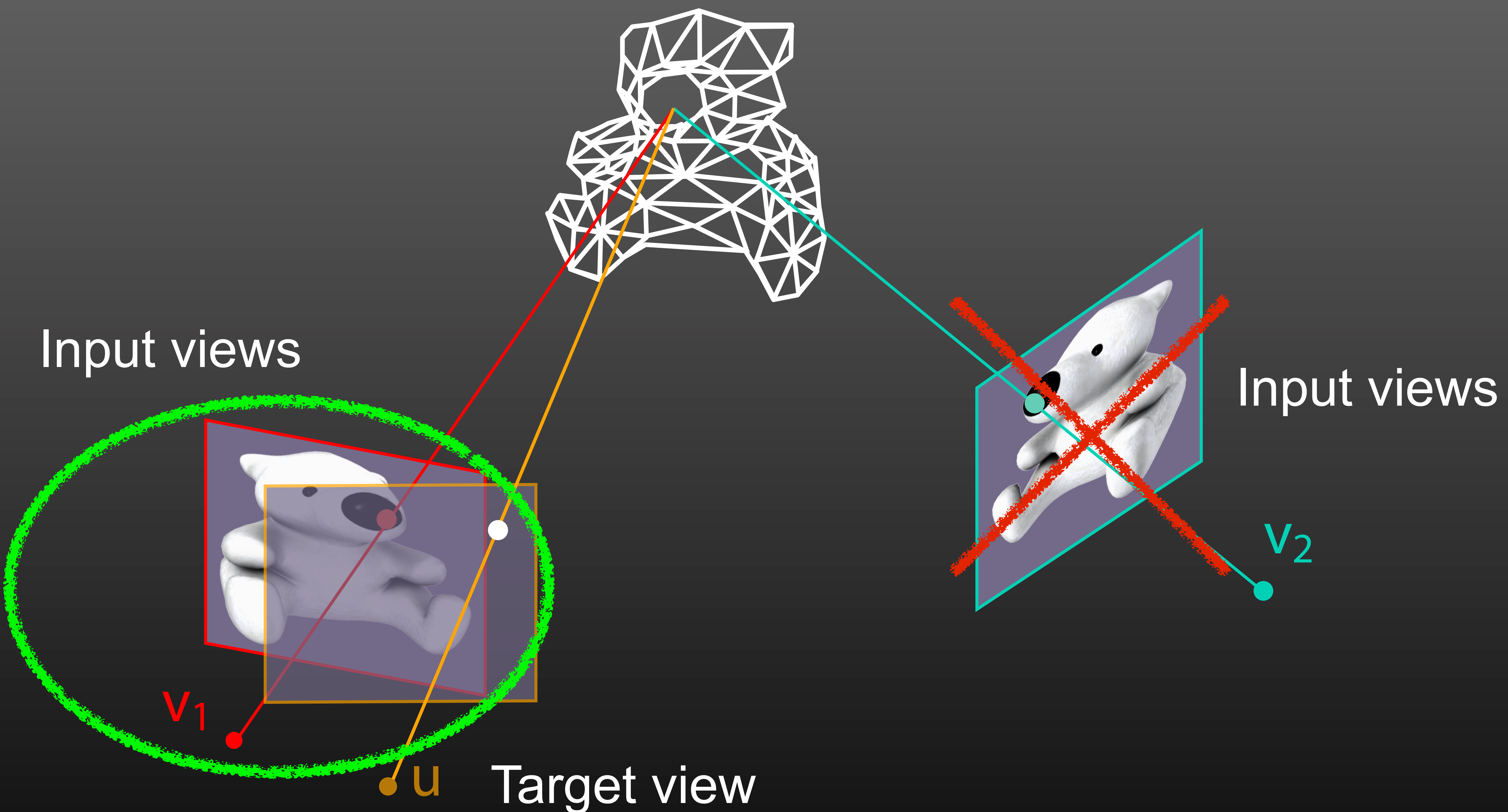
Minimal angular deviation



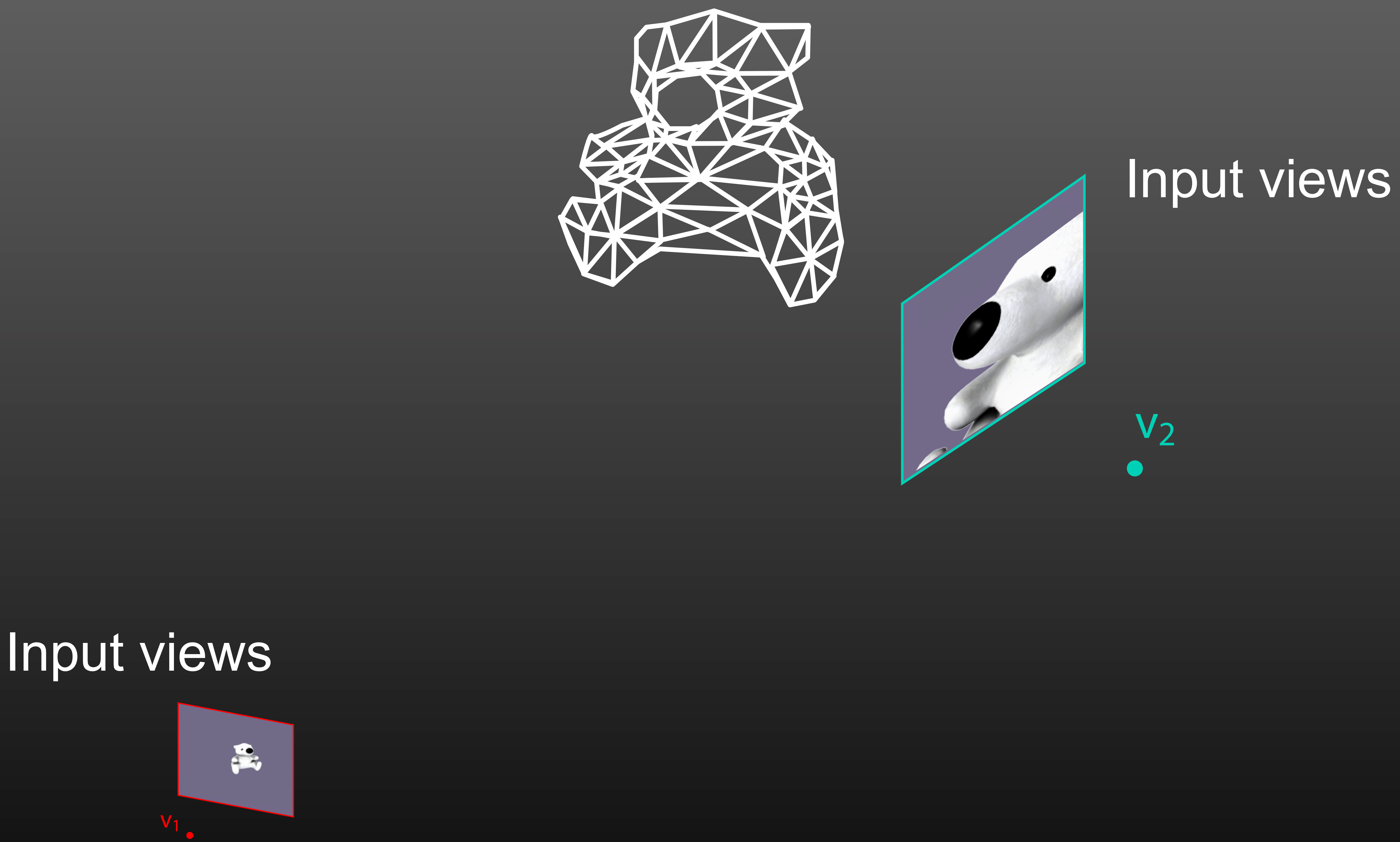
Minimal angular deviation



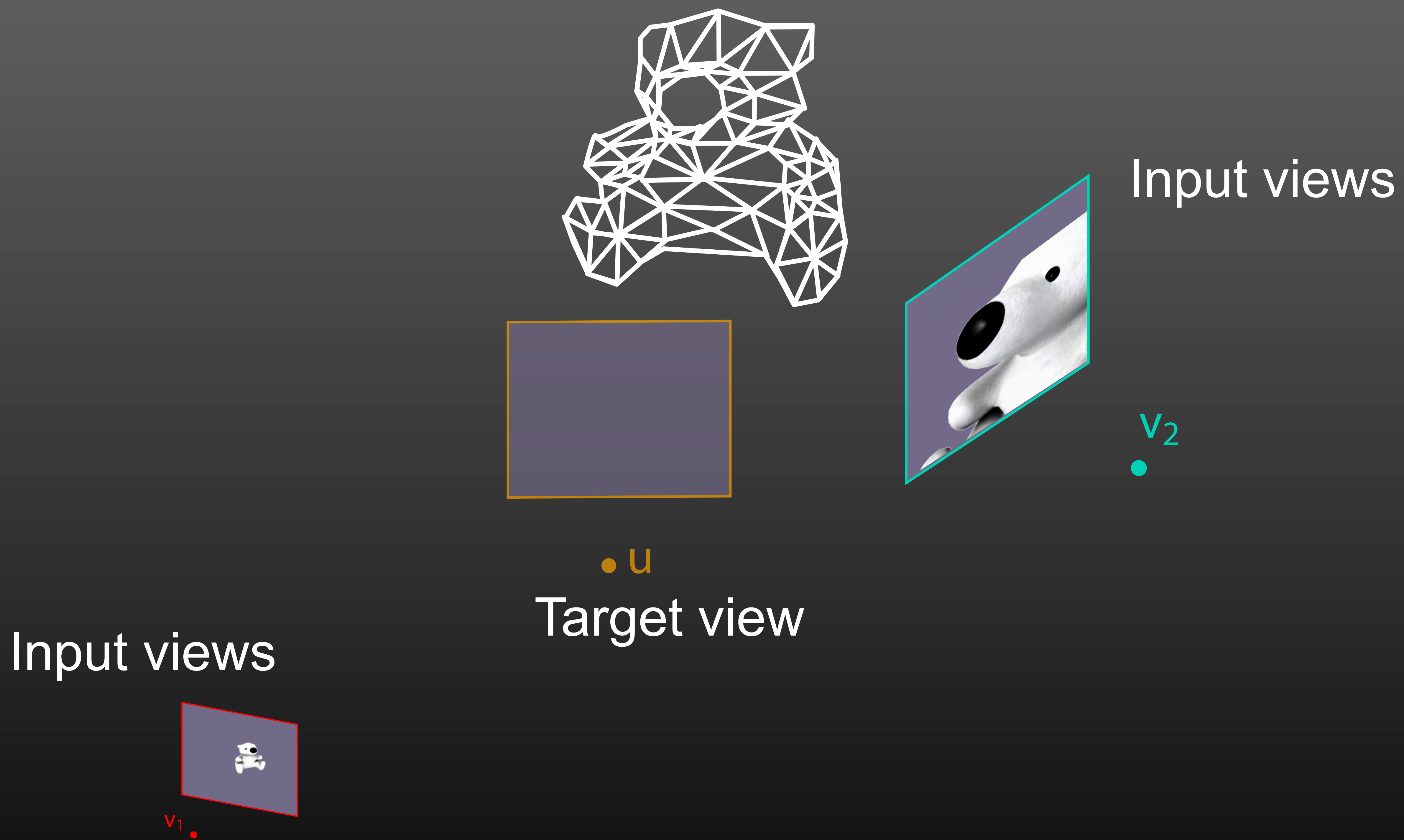
Minimal angular deviation



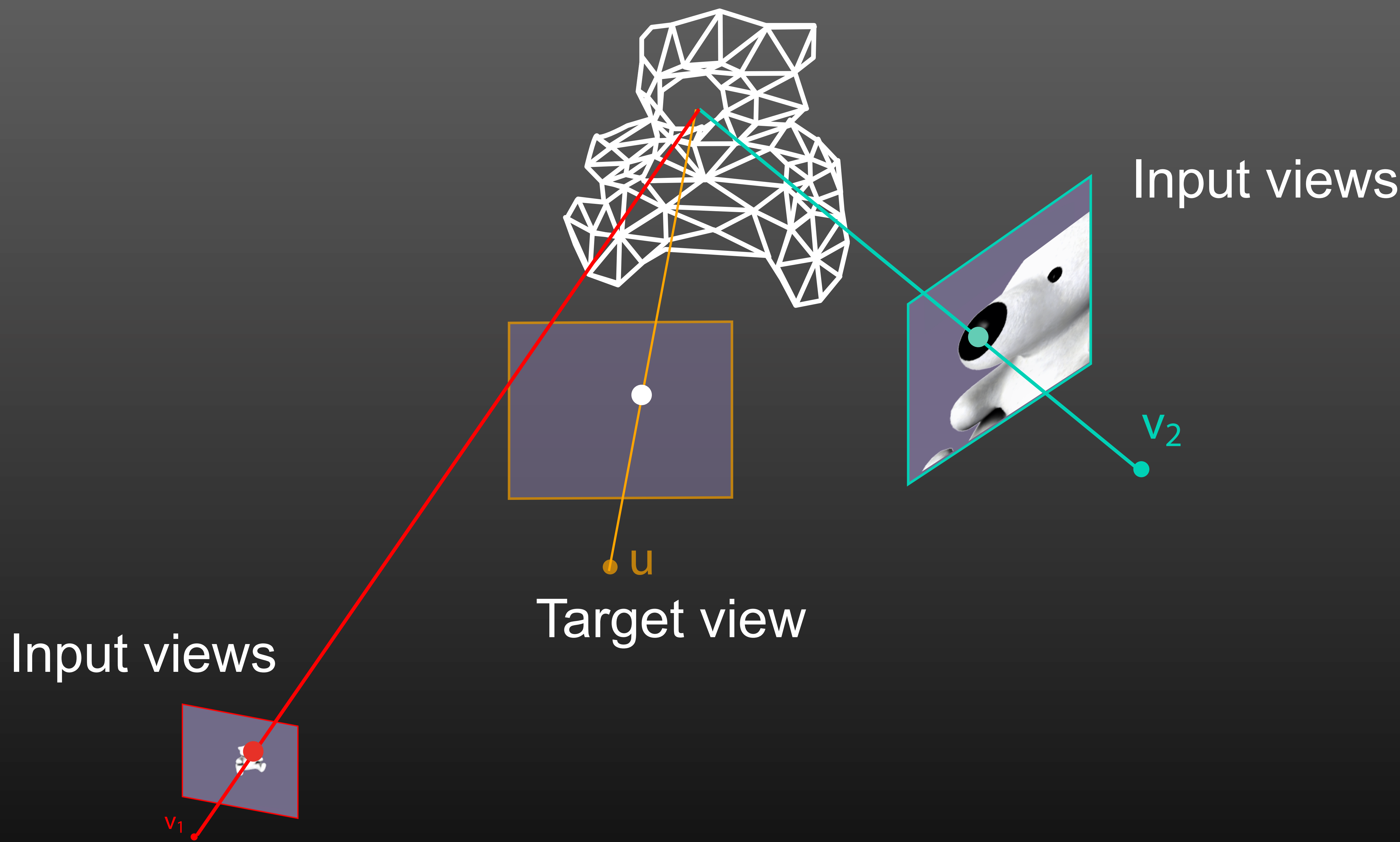
Resolution Sensitivity



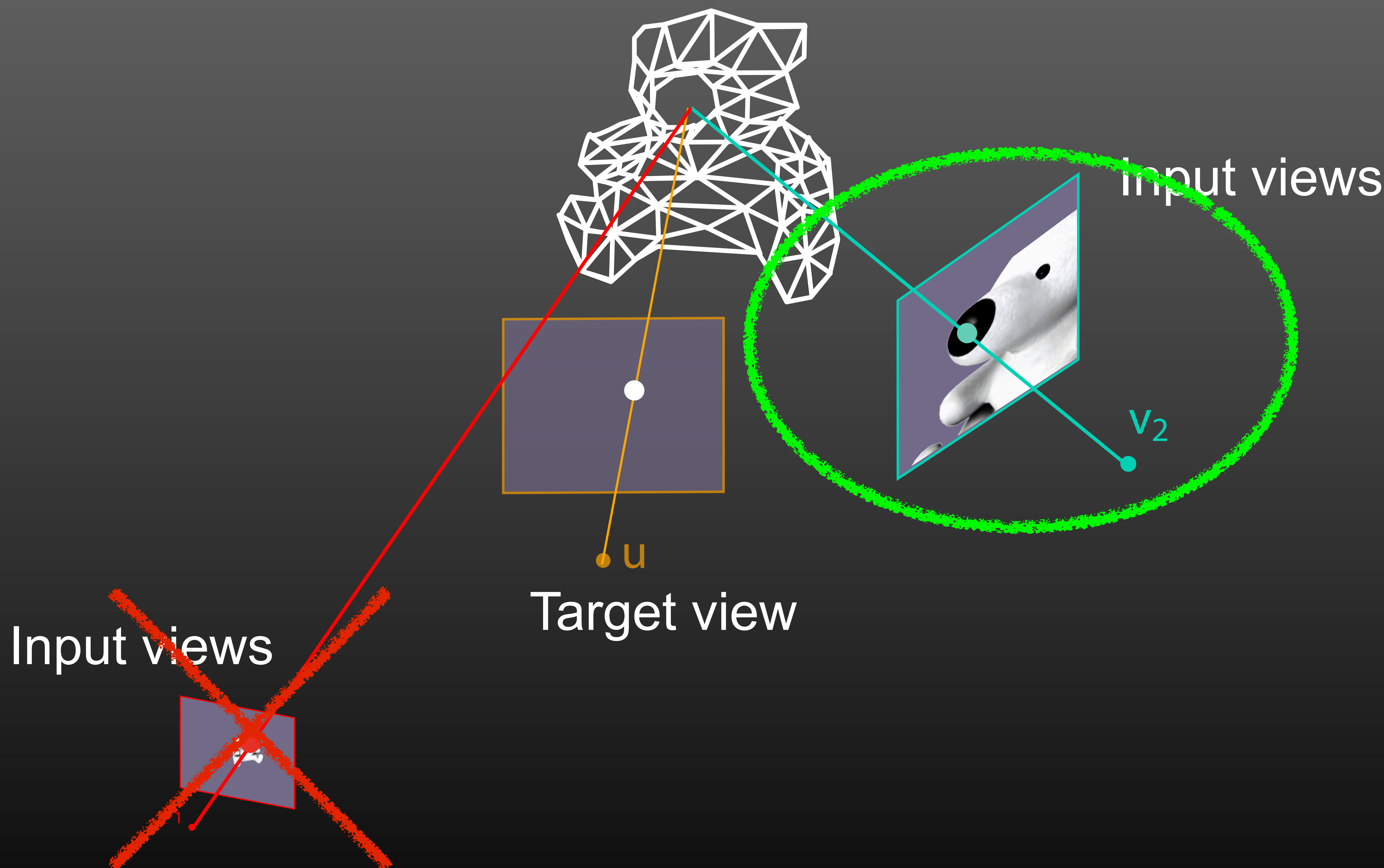
Resolution Sensitivity



Resolution Sensitivity



Resolution Sensitivity



State of the art limitations

For both properties:

- Minimal angular deviation
- Resolution sensitivity

No formal deduction of heuristics

Manual parameter tuning depending on the scene

New properties proposed

- Use of geometric proxies
- Unstructured input
- Minimal angular deviation
  - Epipole consistency
  - Equivalent ray consistency
- Resolution sensitivity
- Formal deduction of heuristics
- Physics-based parameters
- Continuity
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State of the art

Method	Formal deduction Physics-Based Parameters	Resolution sensitivity	Minimal angular deviation
Buehler et al. SIGGRAPH 2001 *Unstructured Lumigraph Rendering*			

State of the art

Method	Formal deduction Physics-Based Parameters	Resolution sensitivity	Minimal angular deviation
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Keita Takahashi ECCV 2010 *Theory of Optimal View Interpolation with Depth Inaccuracy*			

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Our method CVPR 2014			

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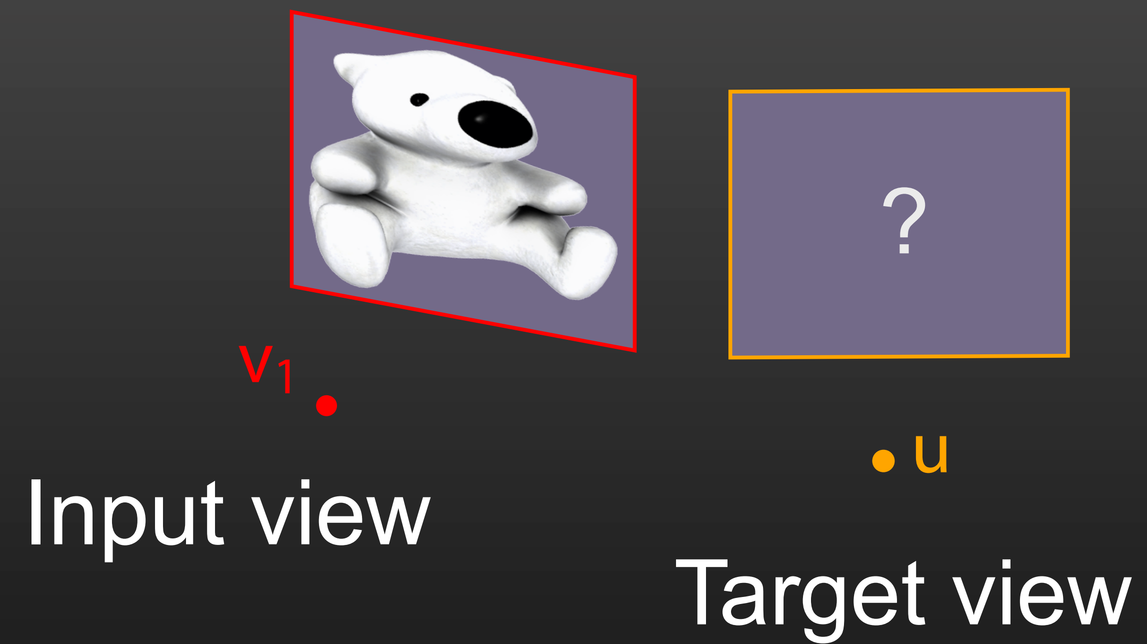
Bayesian Approach: Inverse Problem



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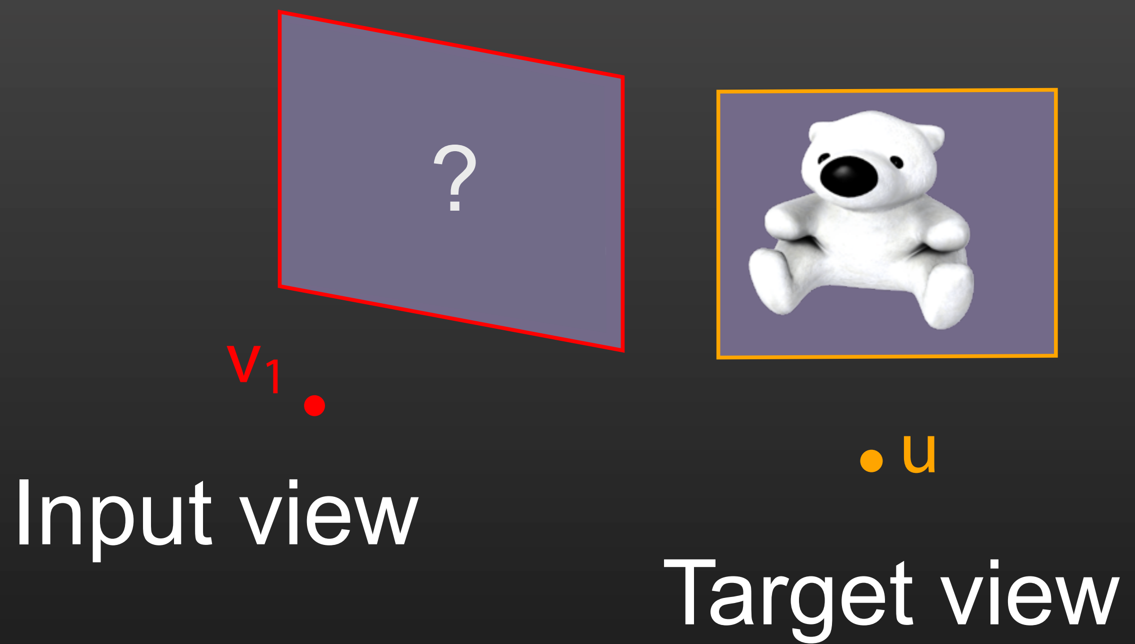

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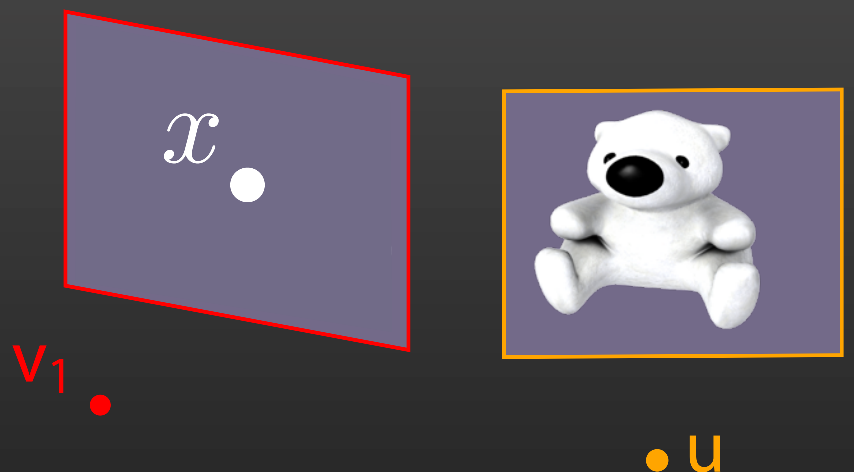
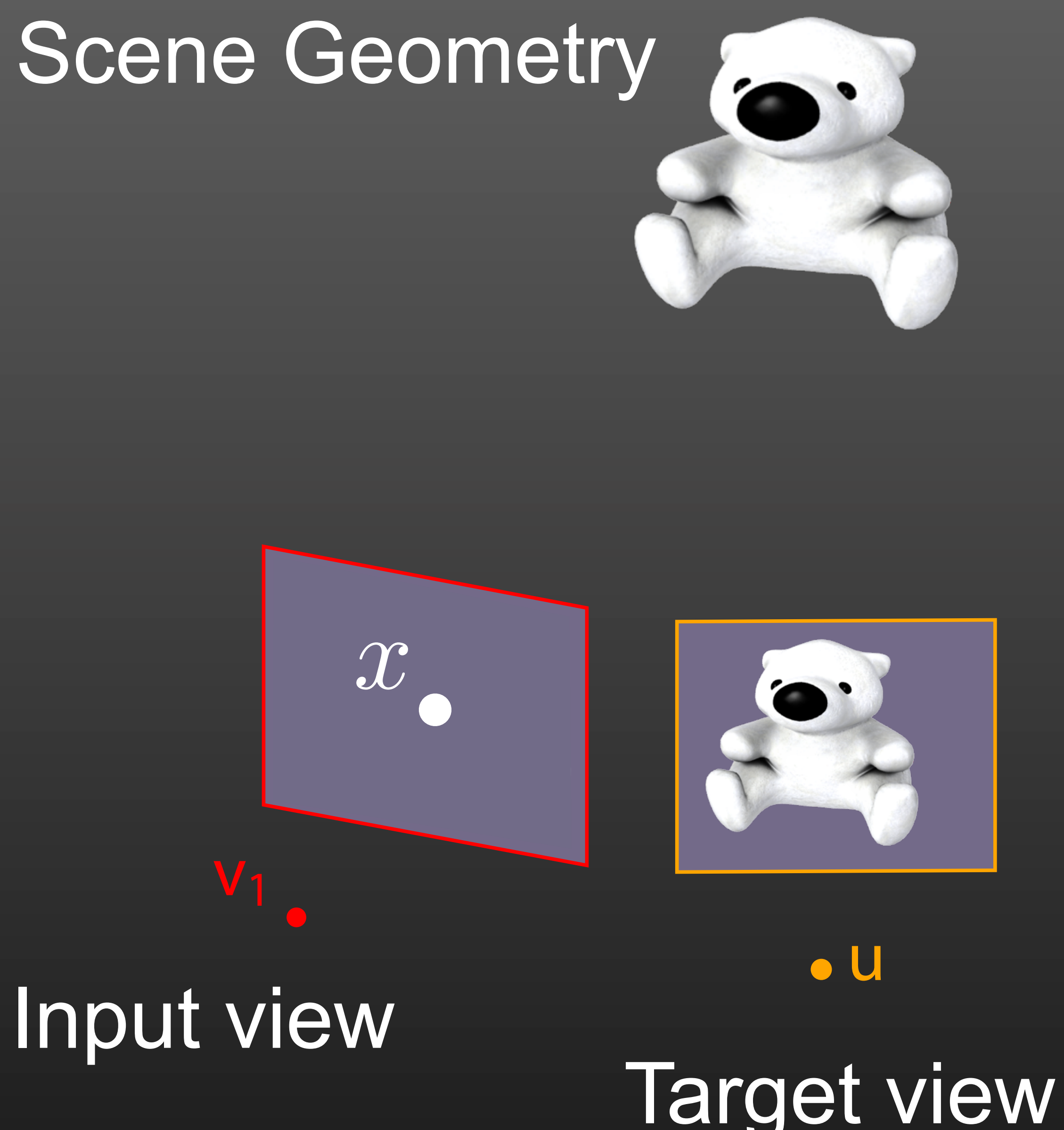


Input view

Target view

Bayesian Approach: Inverse Problem



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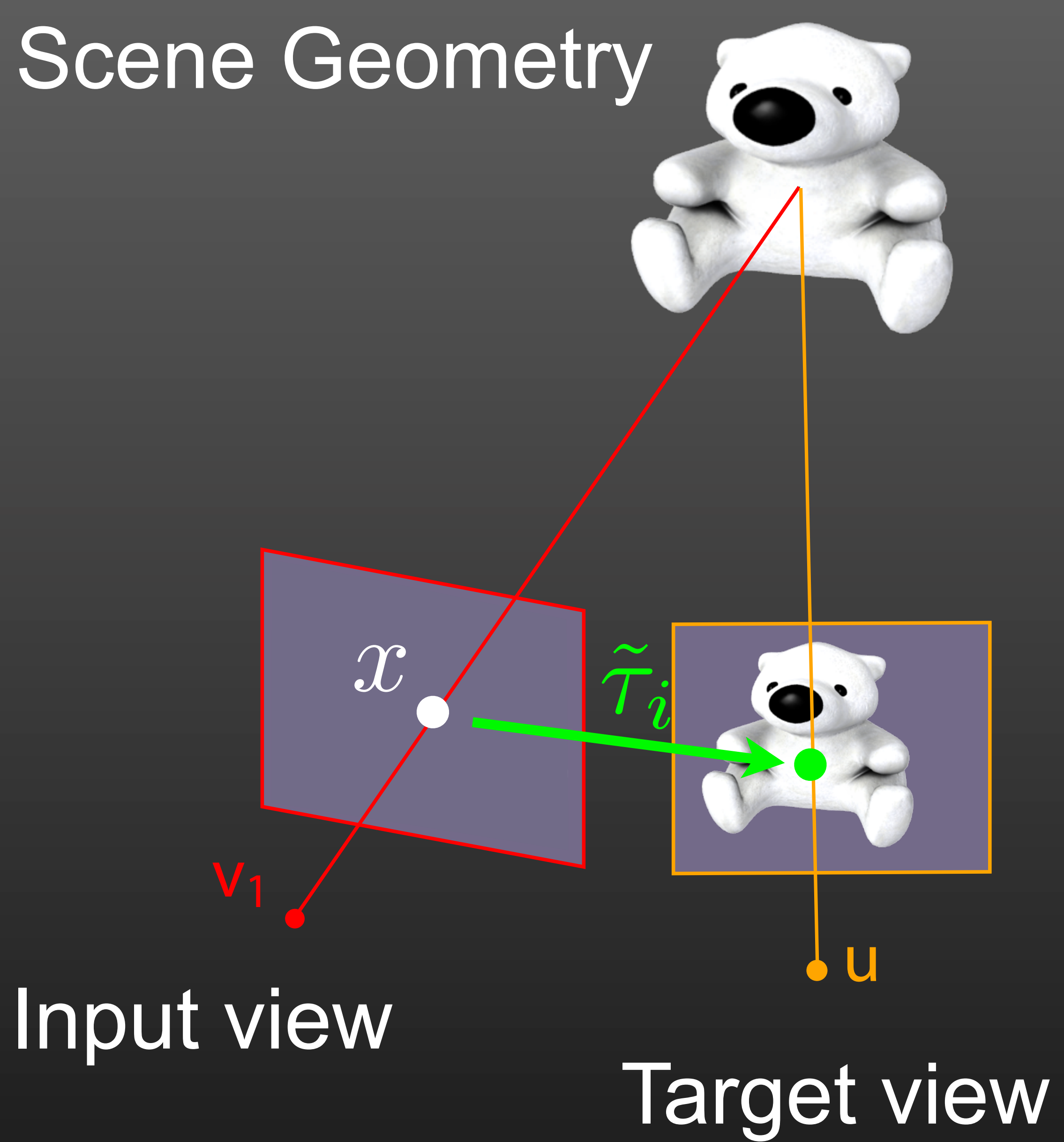

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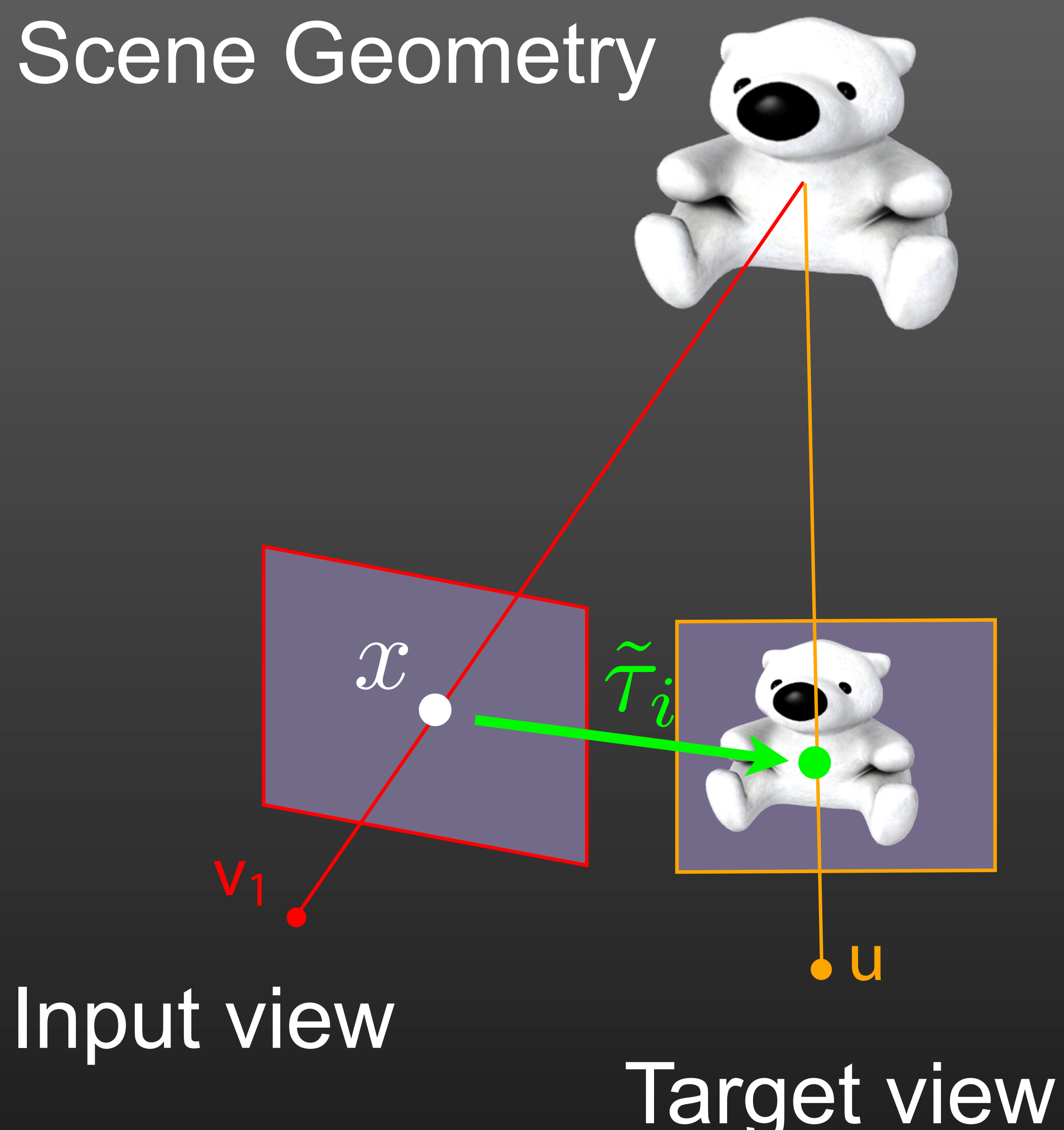
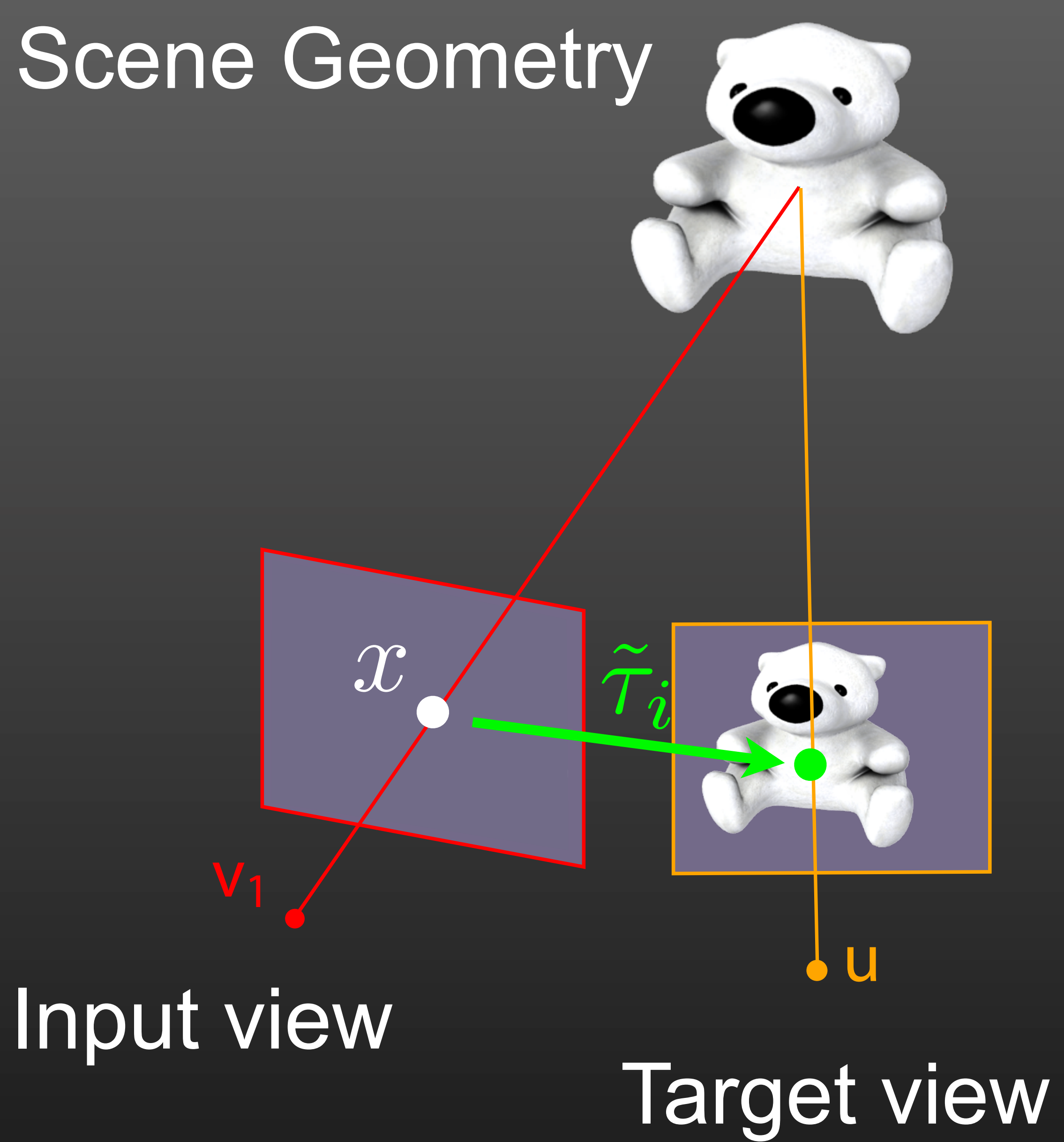


Perfect image

$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

Bayesian Approach: Inverse Problem



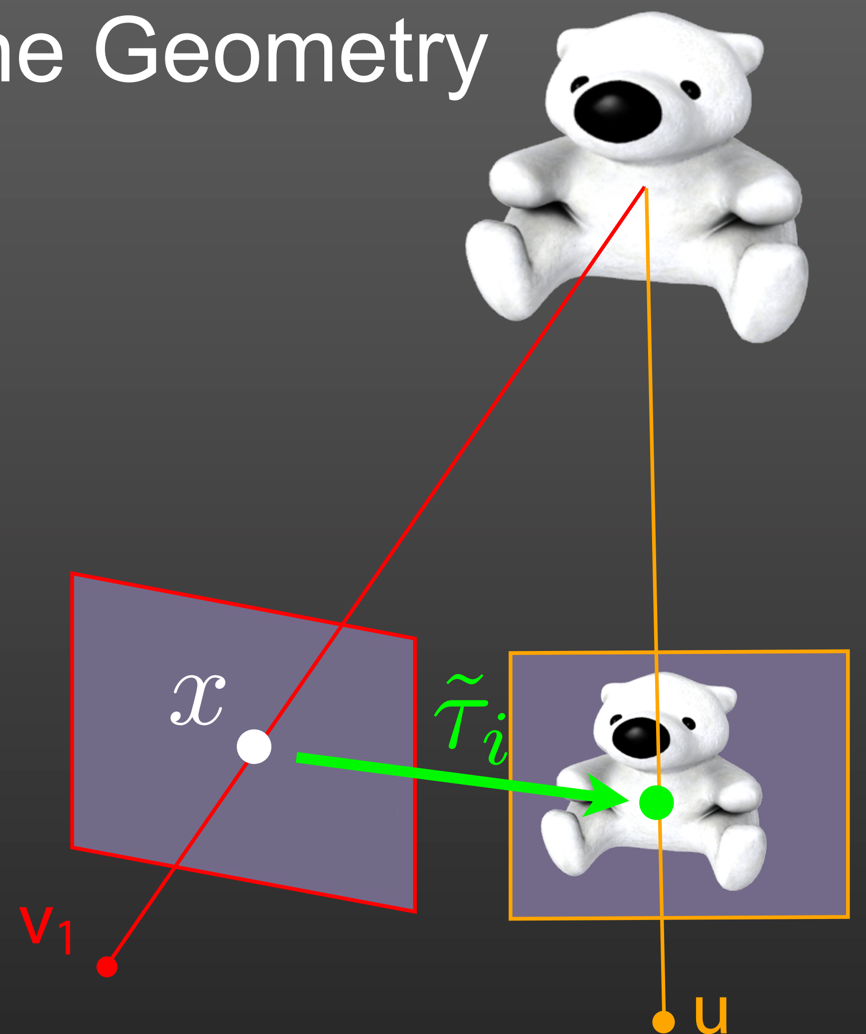
Perfect image

$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

Generative Model
Perfect image formation
description

Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

Perfect image

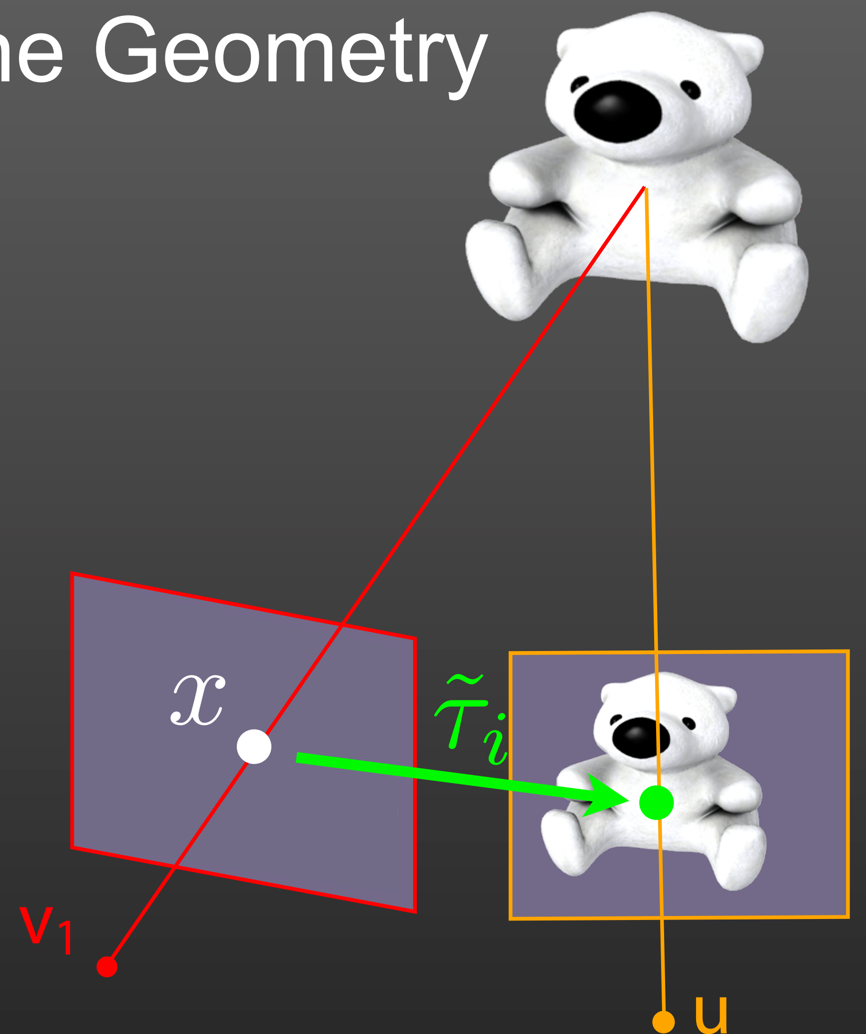
$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

Generative Model
Perfect image formation
description

assuming Lambertian model

Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

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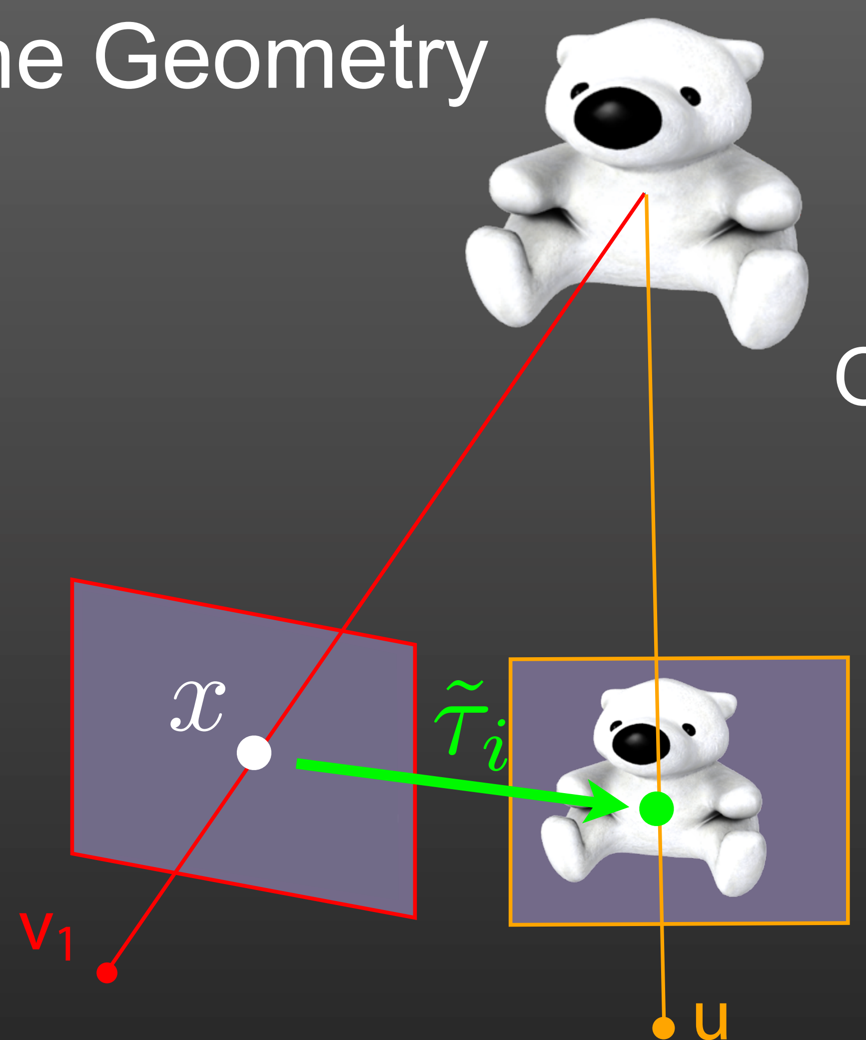
Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

Perfect image

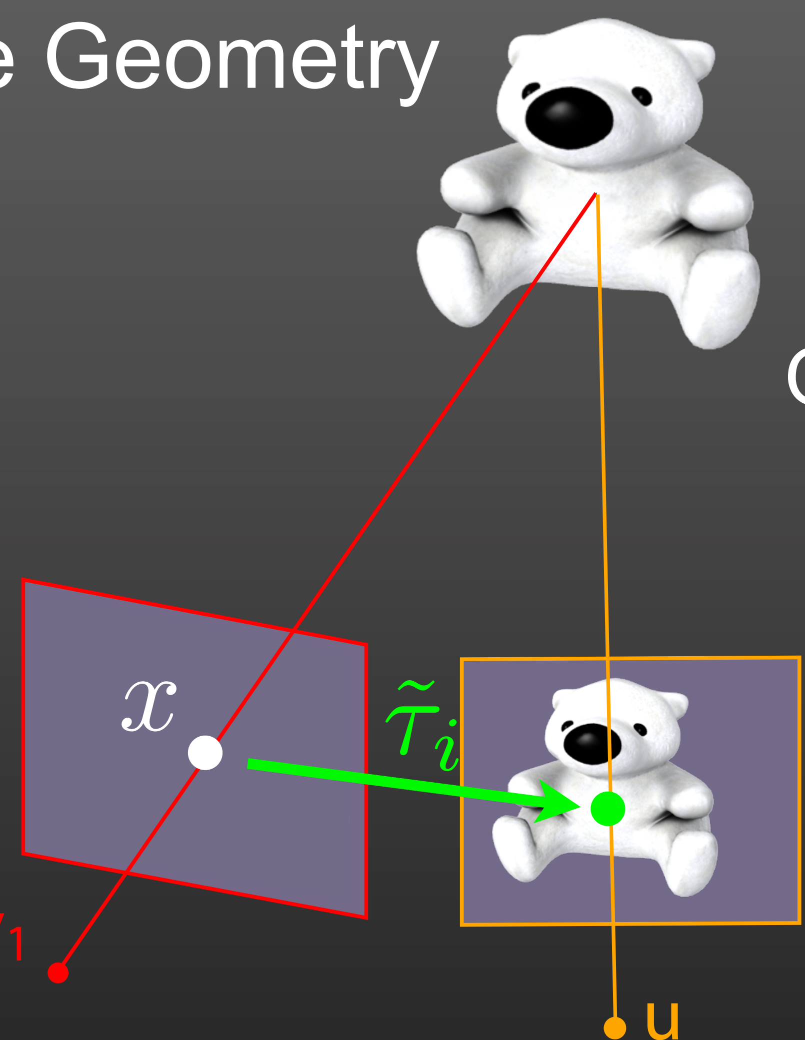
$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

Observed image

$$v_i(x) =$$

Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

Perfect image

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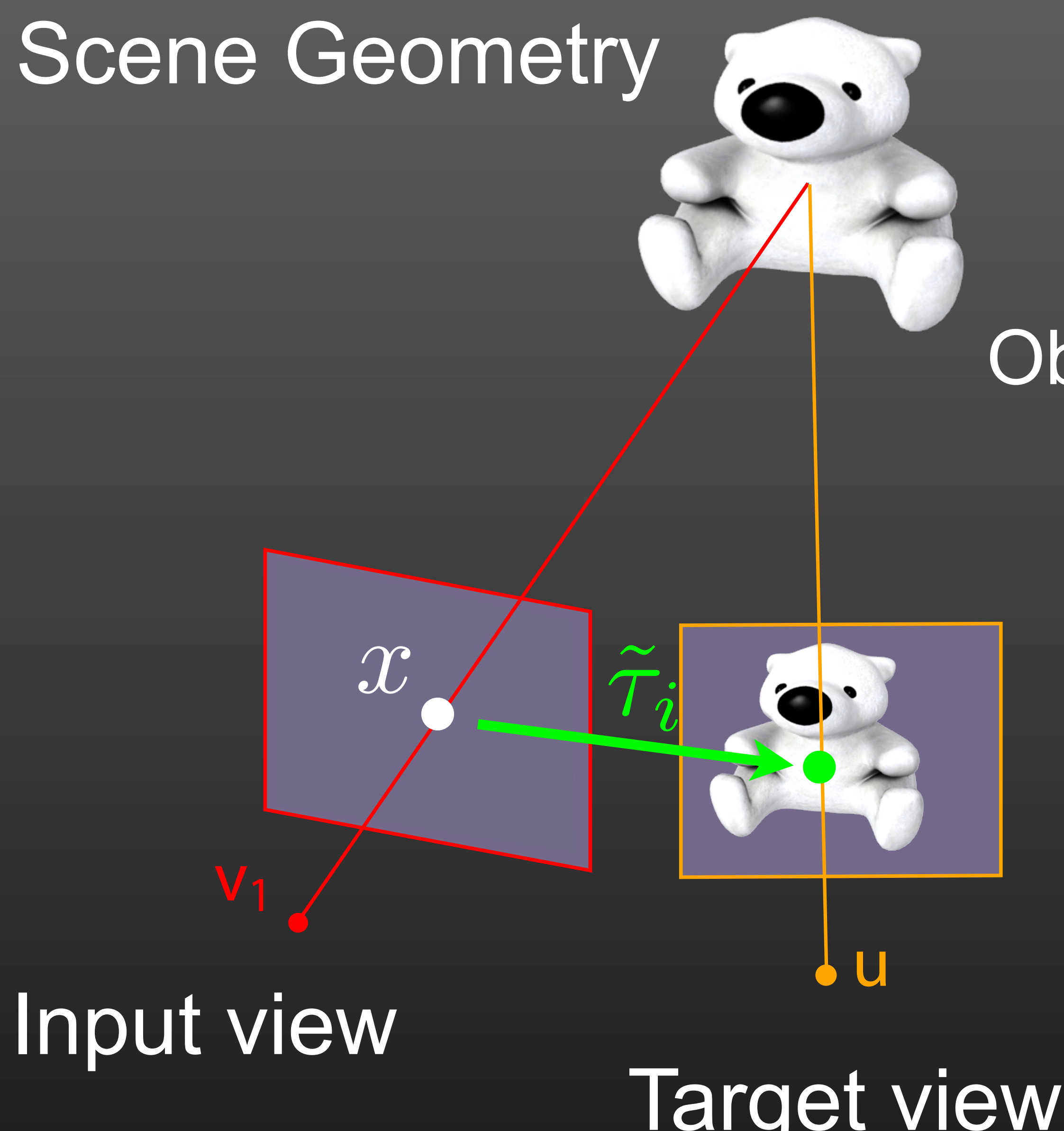
Observed image

$$v_i(x) = \tilde{v}_i(x)$$

Bayesian Approach: Inverse Problem



Perfect image

$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

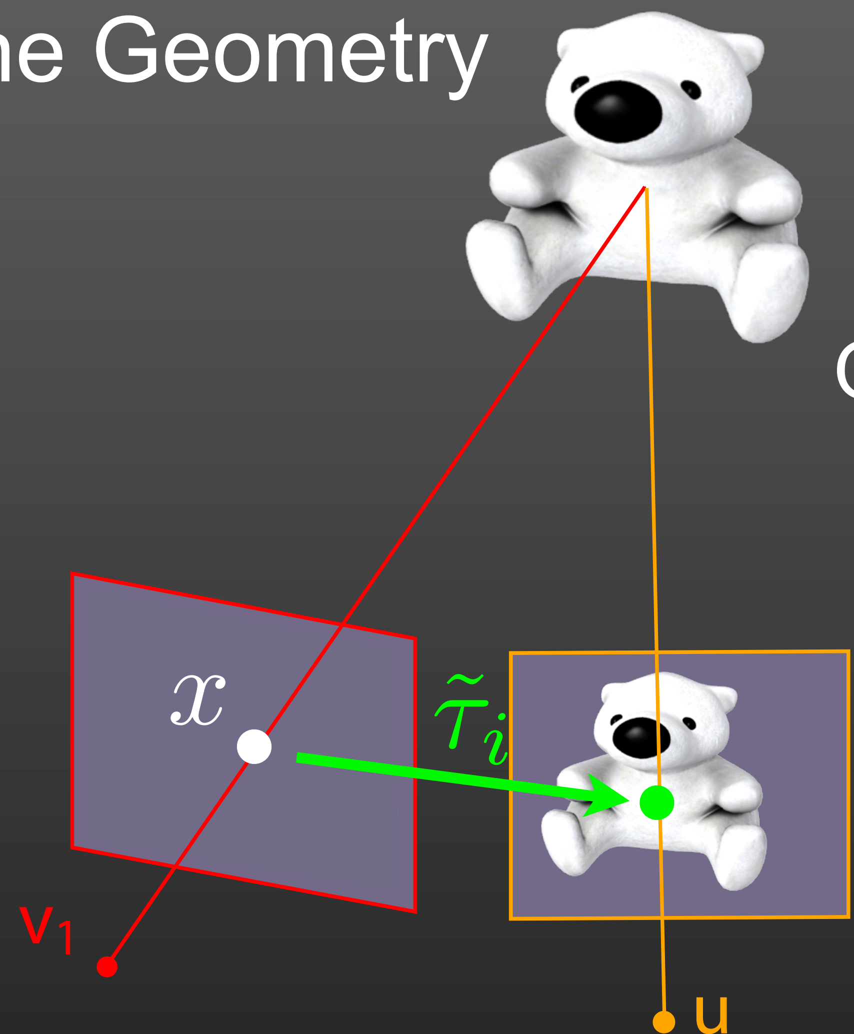
Observed image

Sensor noise

$$v_i(x) = \tilde{v}_i(x) + e_s(x)$$

Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

Perfect image

$$\tilde{v}_i(x) = (u \circ \tilde{\tau}_i)(x)$$

Observed image

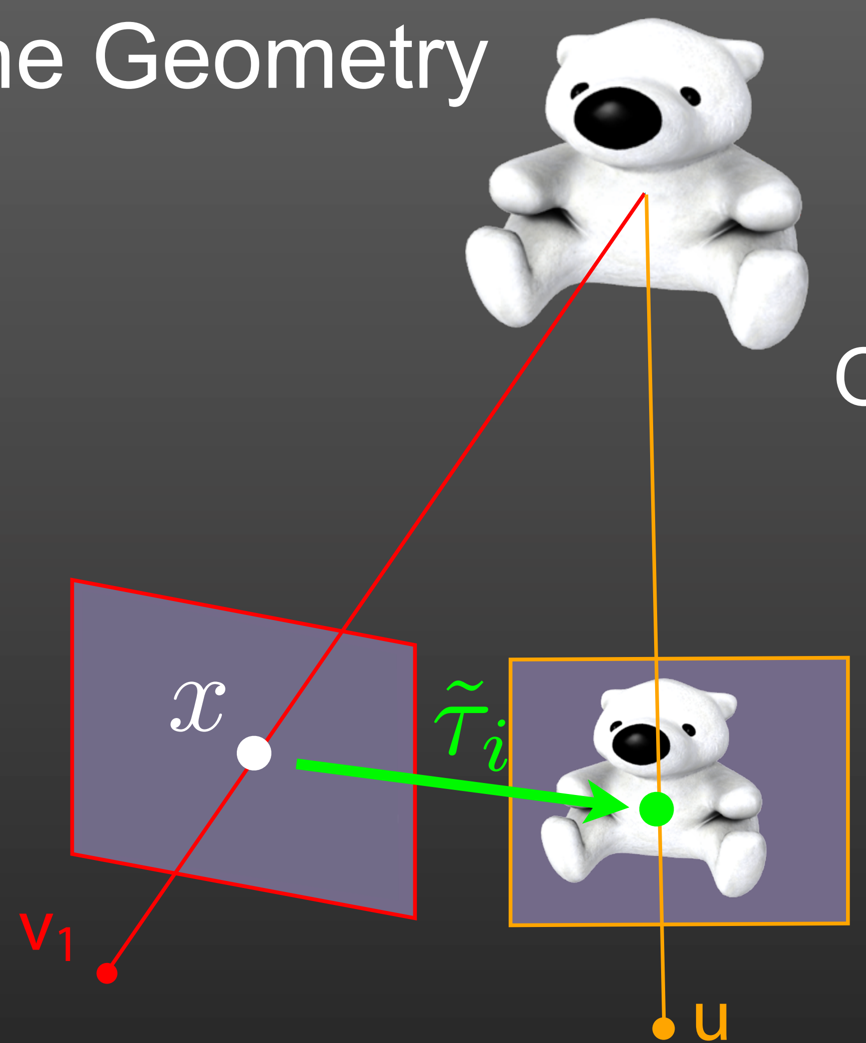
Sensor noise

$$v_i(x) = \tilde{v}_i(x) + e_s(x)$$

Gaussian distribution

Bayesian Approach: Inverse Problem

Scene Geometry



Input view

Target view

Perfect image

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Observed image

Sensor noise

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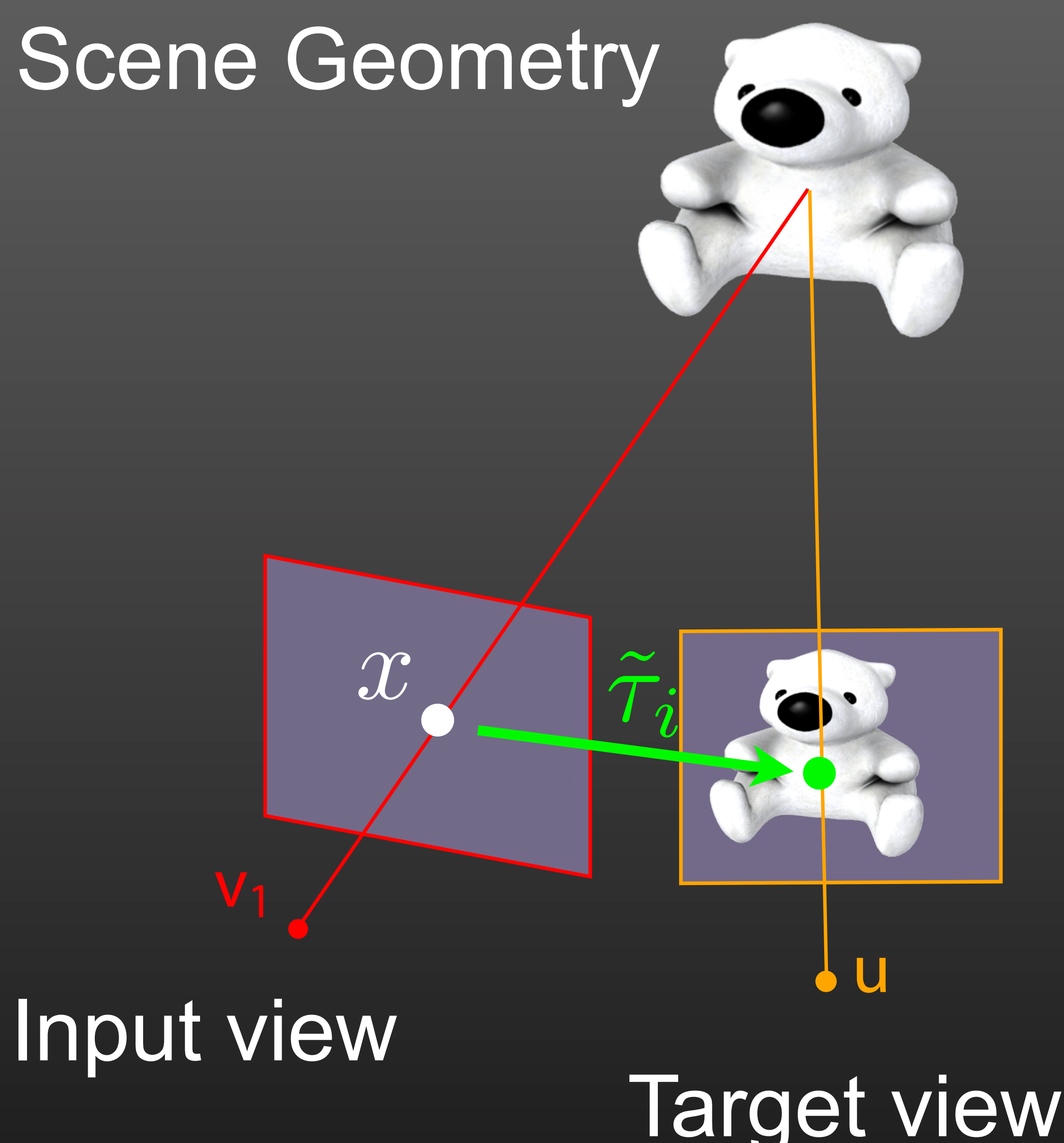
Gaussian distribution

Least squares minimisation problem

Bayesian Approach: Inverse Problem

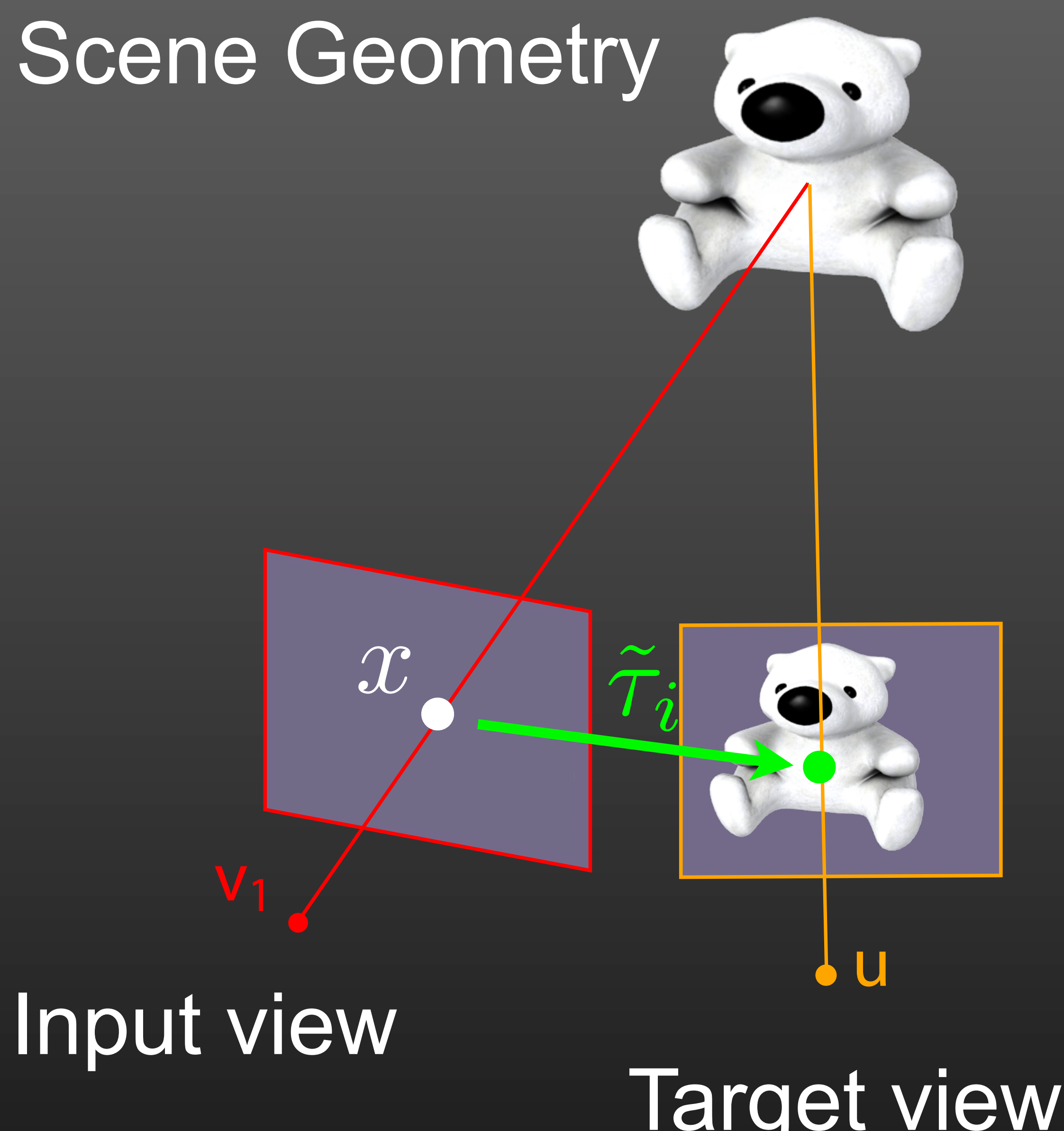


Spatial and Angular Variational Super-resolution of 4D Light Fields
S. Wanner and B. Goldluecke ECCV 2012

$$v_i(x) = \tilde{v}_i(x) + e_s(x)$$

- Physics based ✓
- Resolution sensibility ✓
- Minimal angular deviation ✗

Bayesian Approach: Inverse Problem



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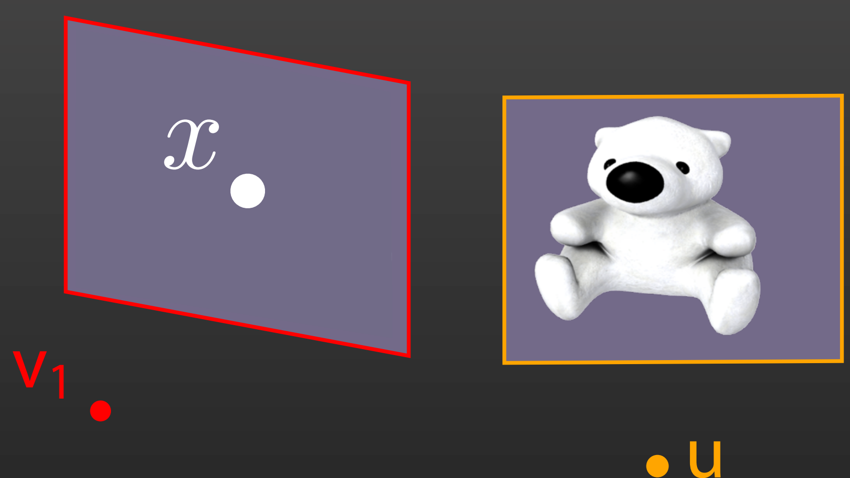
WHY?

Bayesian Approach: Proposed Method

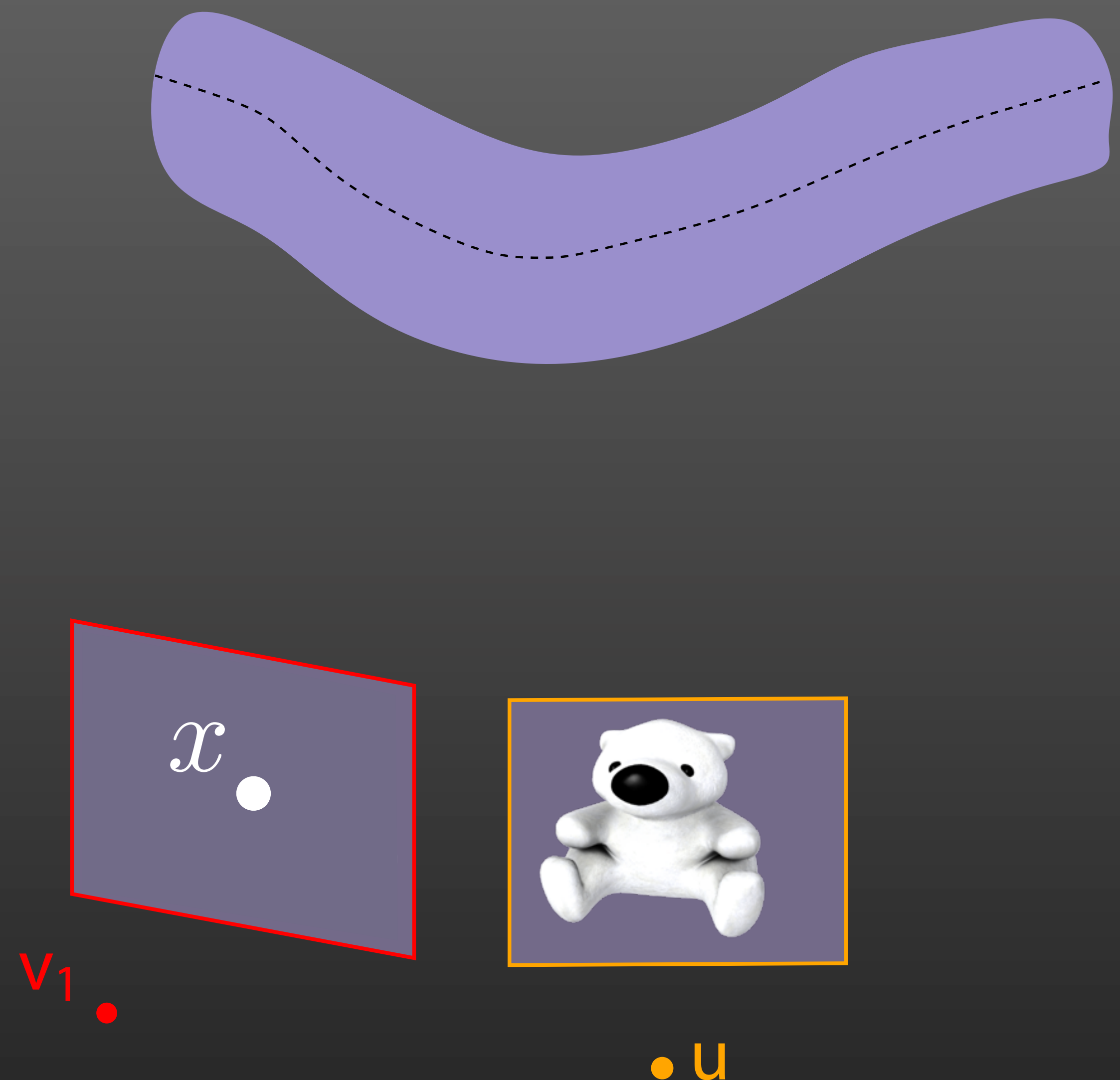
Scene Geometry



Input view

Target view

Bayesian Approach: Proposed Method



Input view

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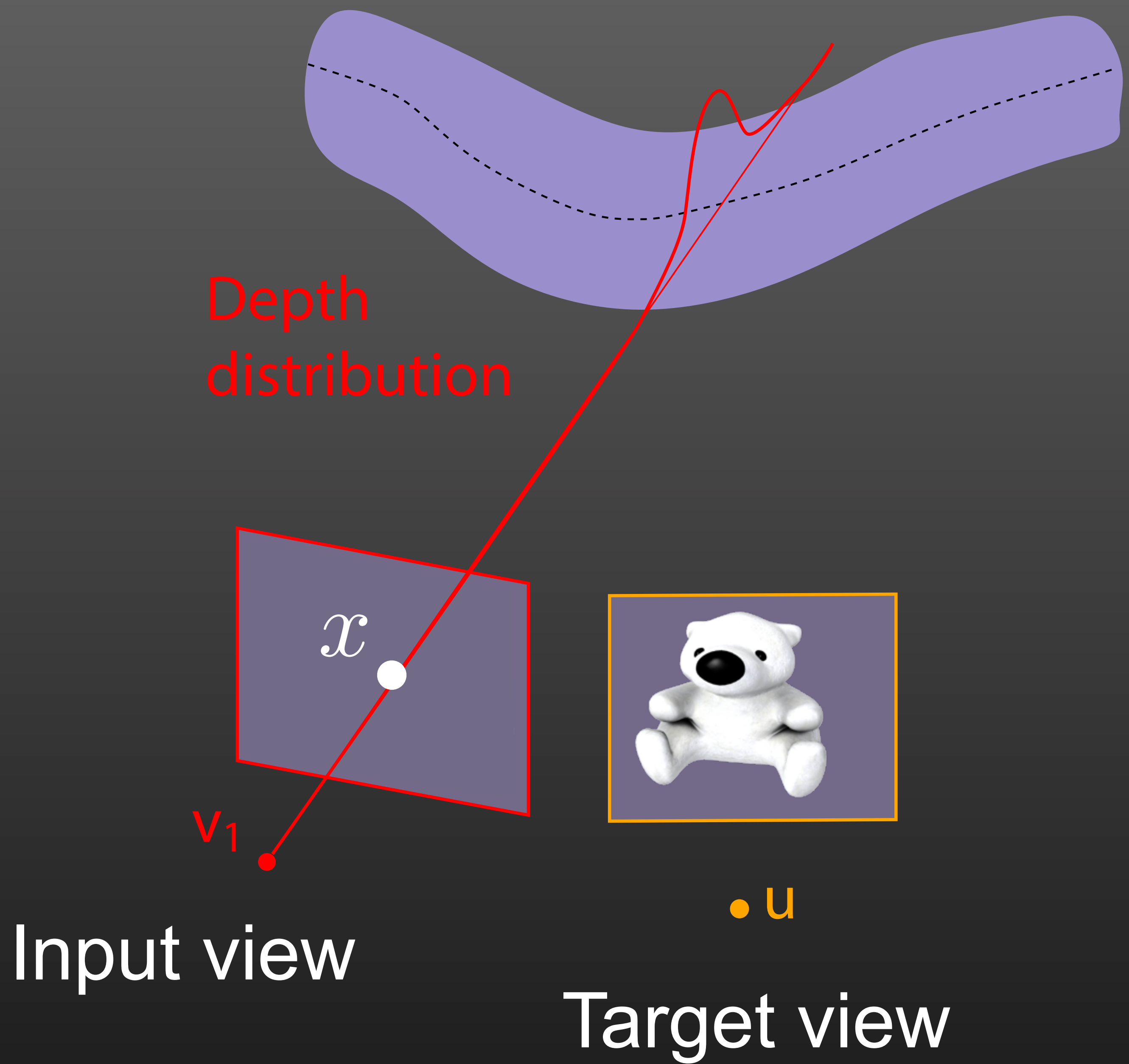

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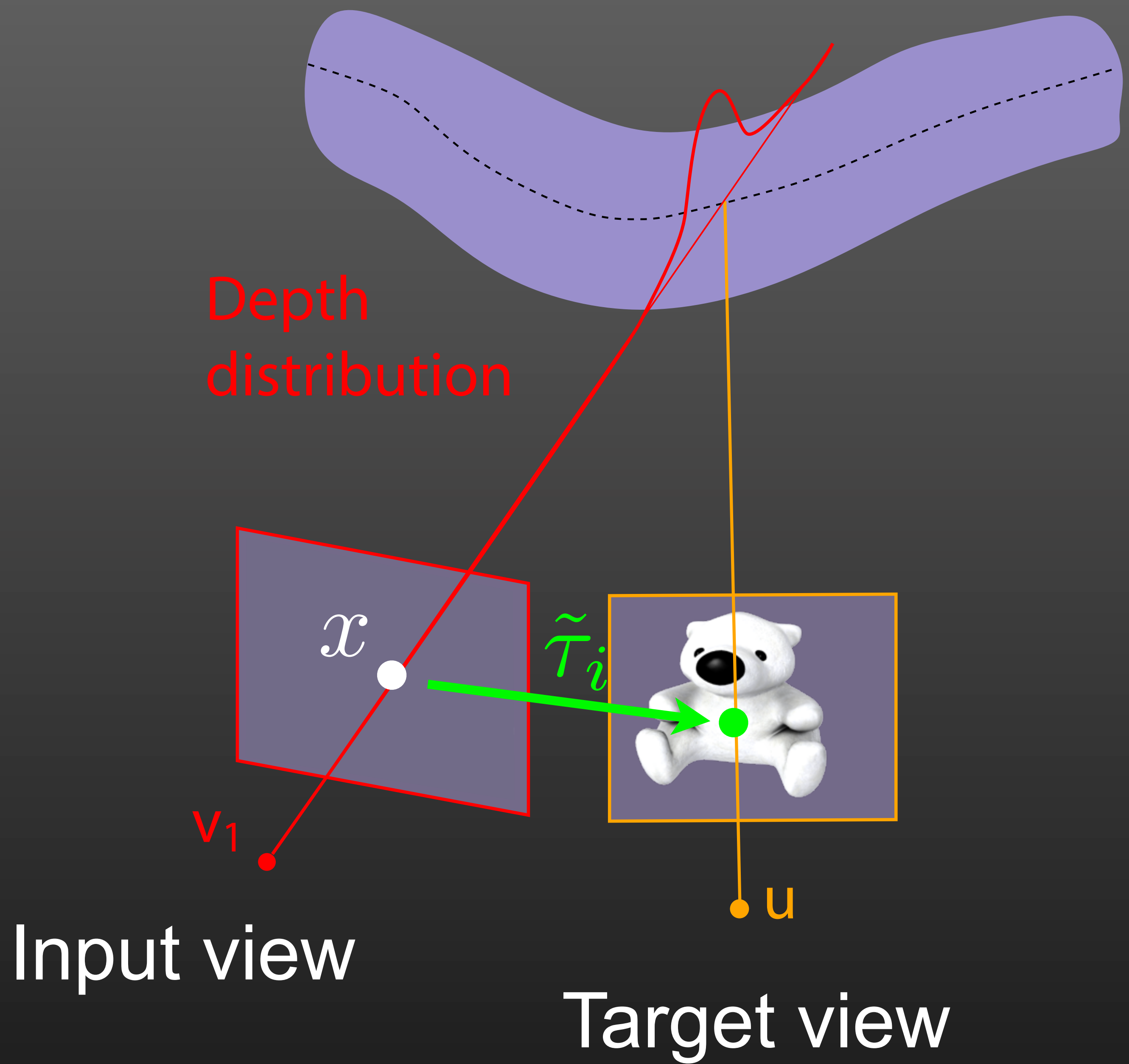

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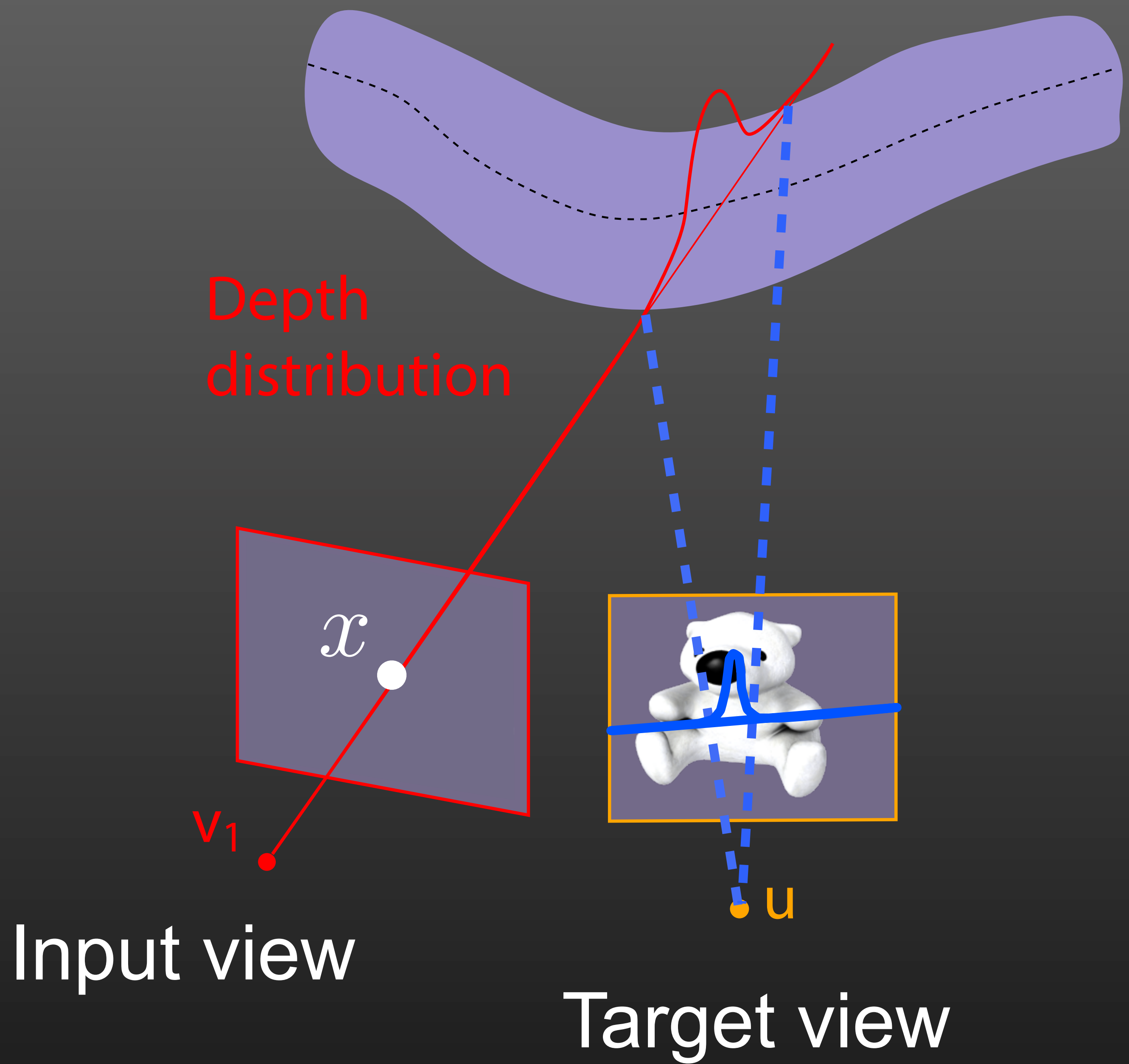

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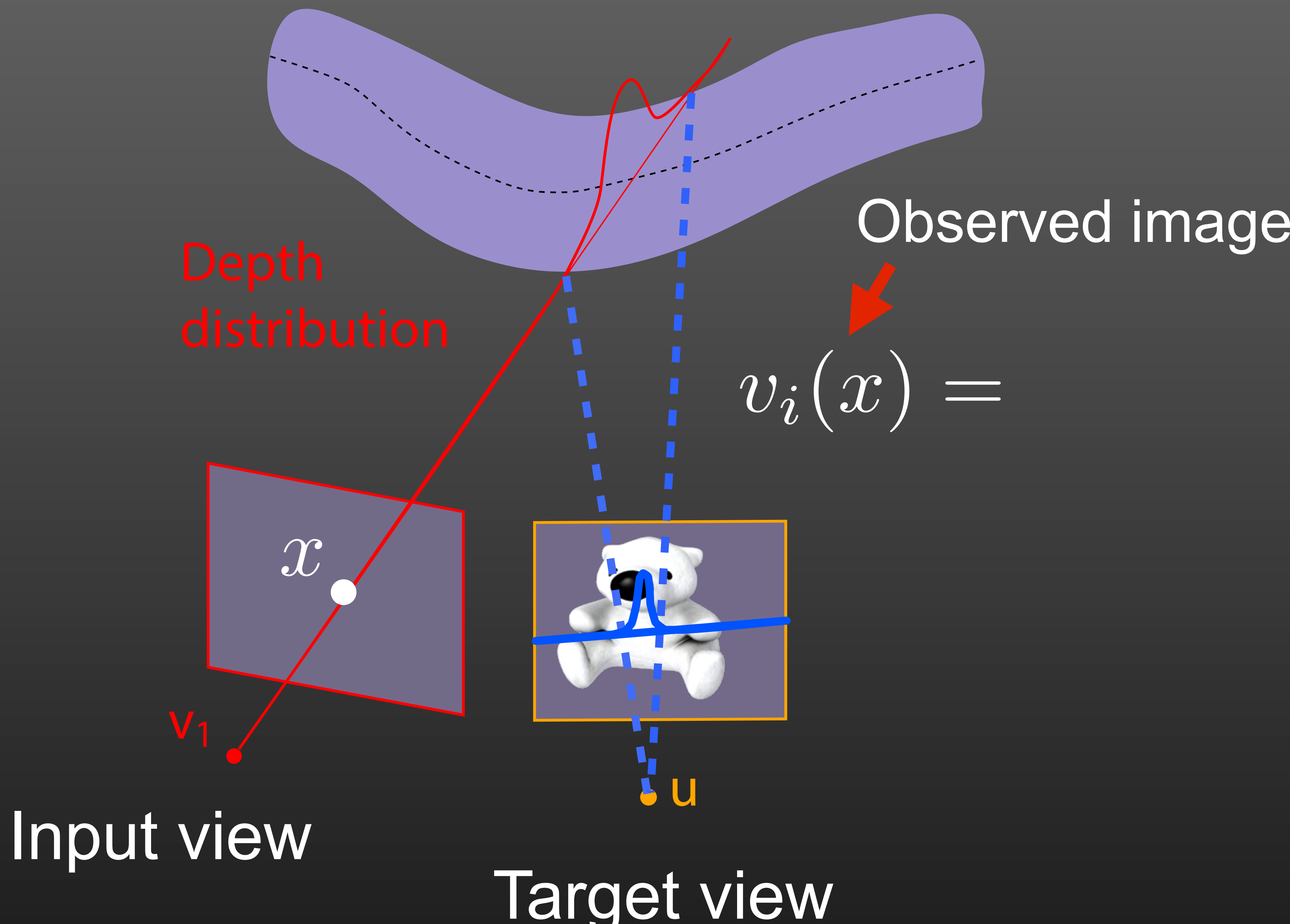

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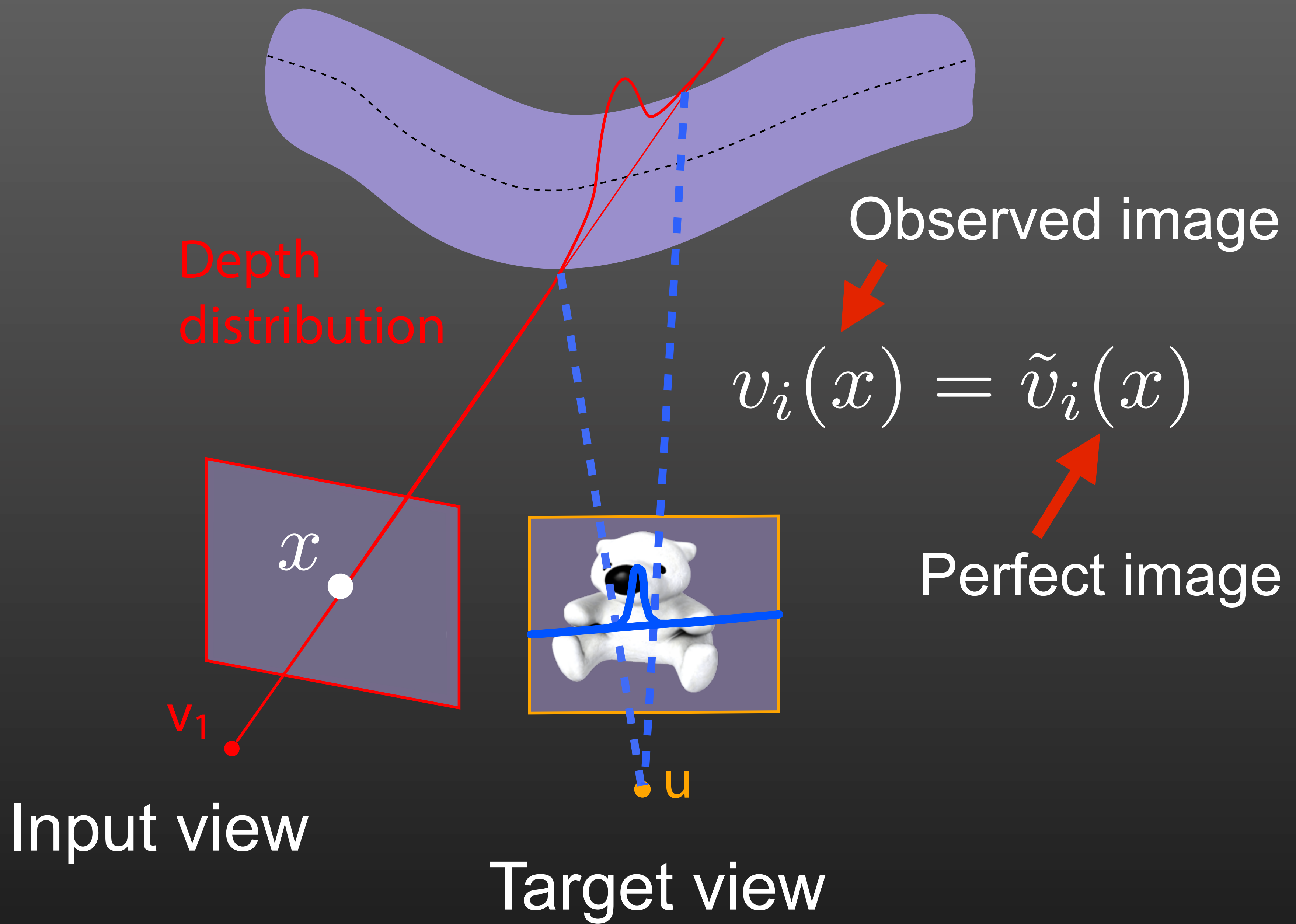

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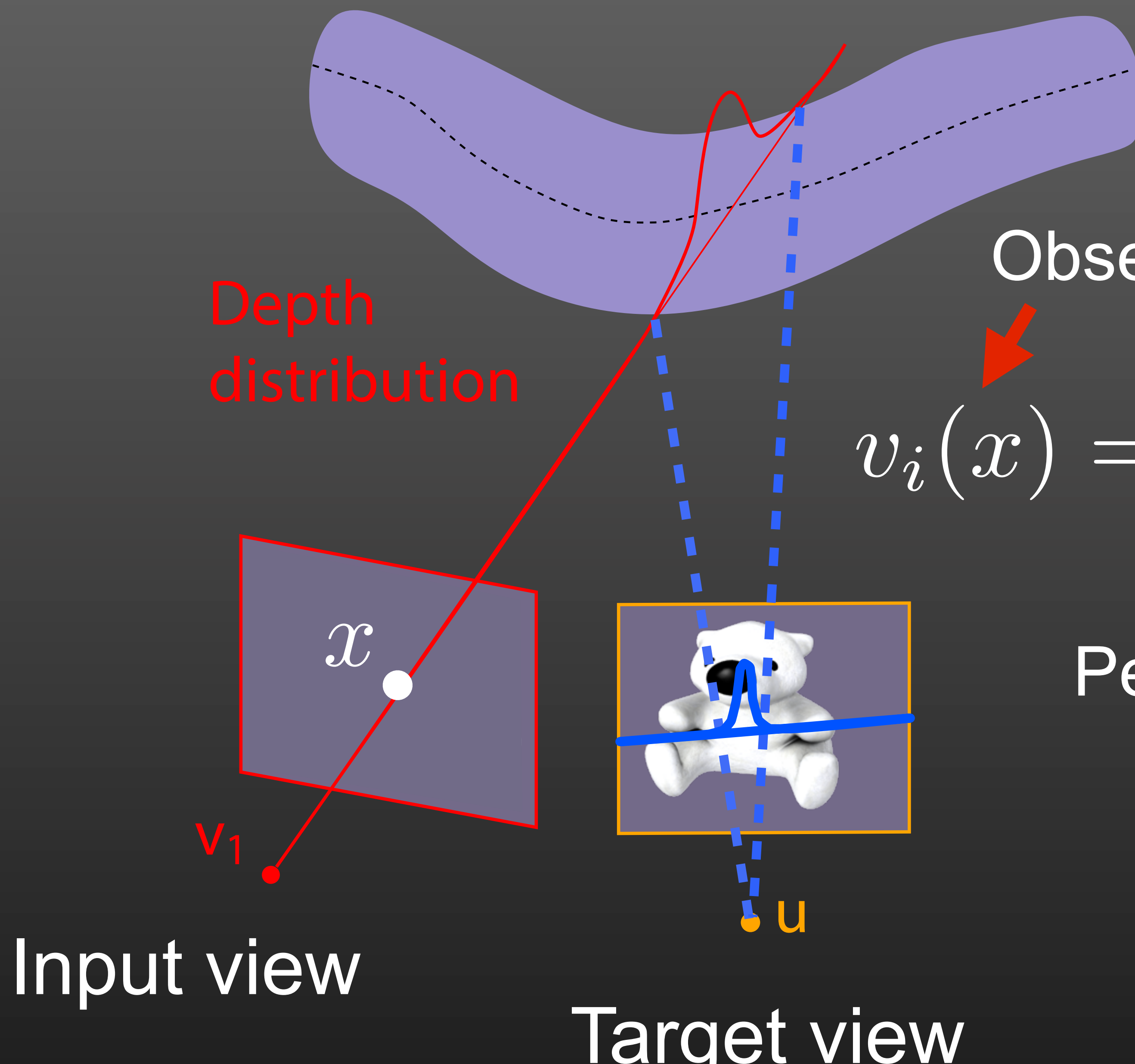


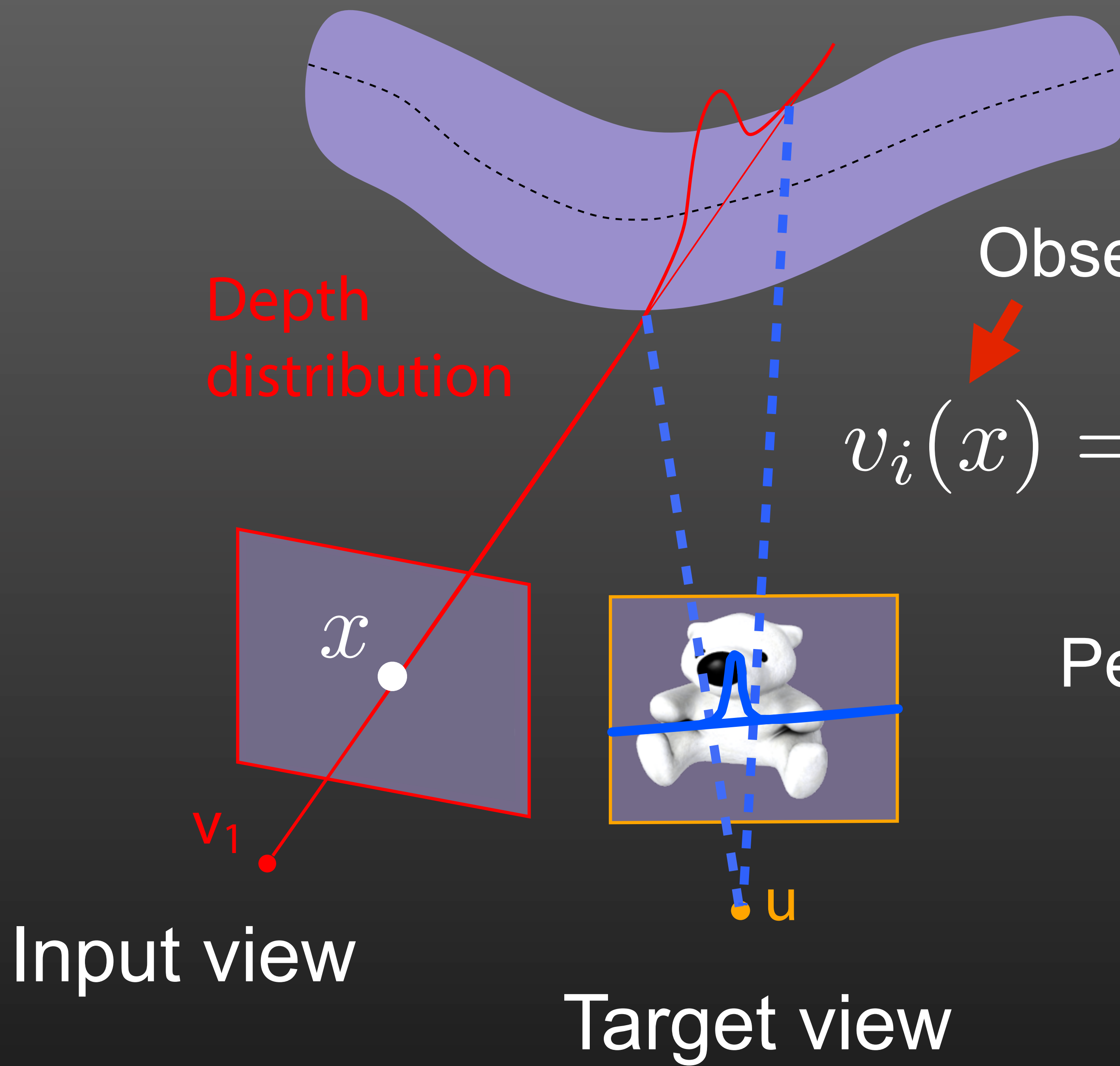
Observed image

Sensor noise

$$v_i(x) = \tilde{v}_i(x) + e_s(x)$$

Perfect image

Bayesian Approach: Proposed Method



Observed image

Sensor noise

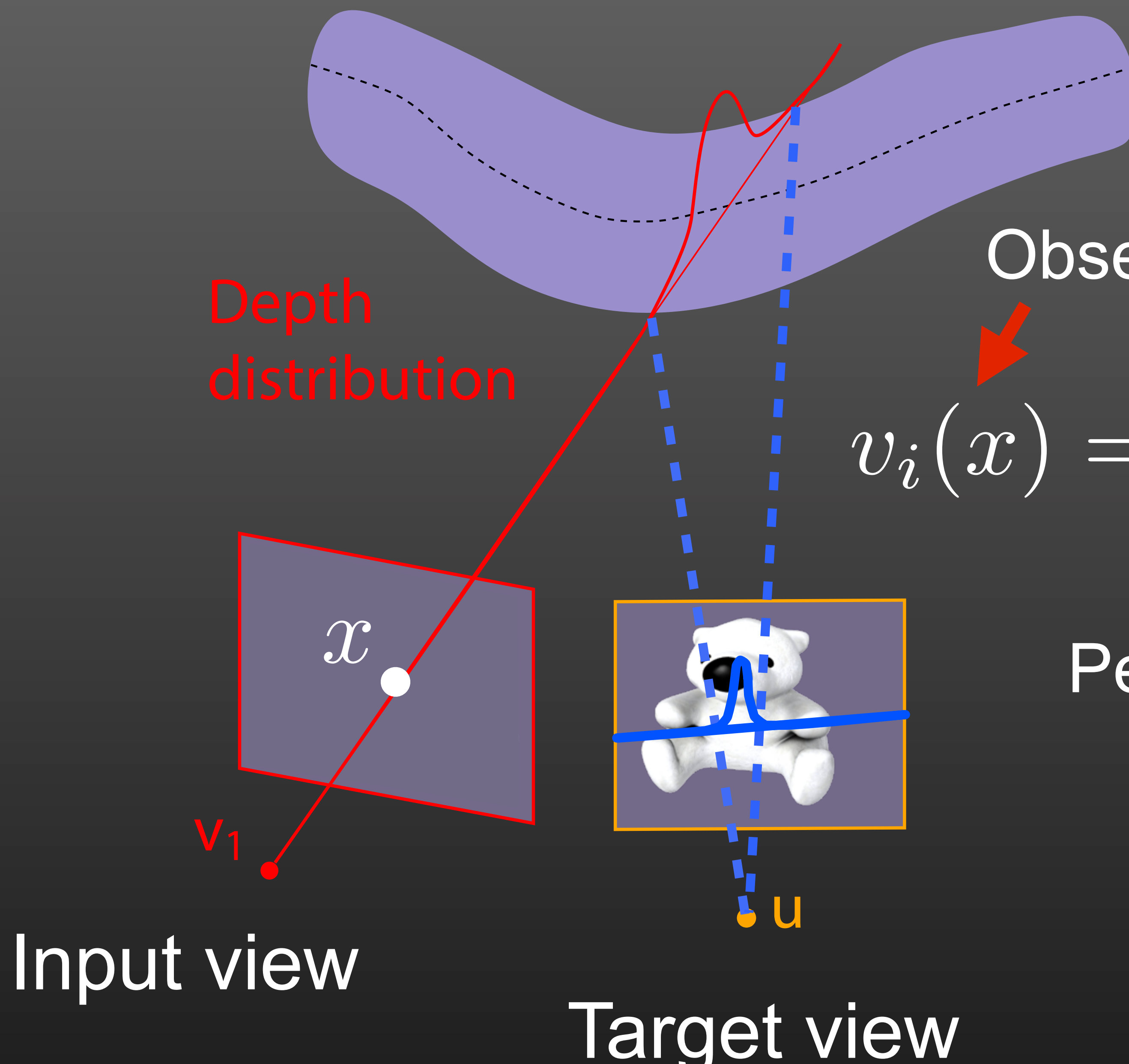
$$v_i(x) = \tilde{v}_i(x) + e_s(x) + e_g(x)$$

Perfect image

Geometric Noise

Bayesian Approach: Proposed Method

details in the paper



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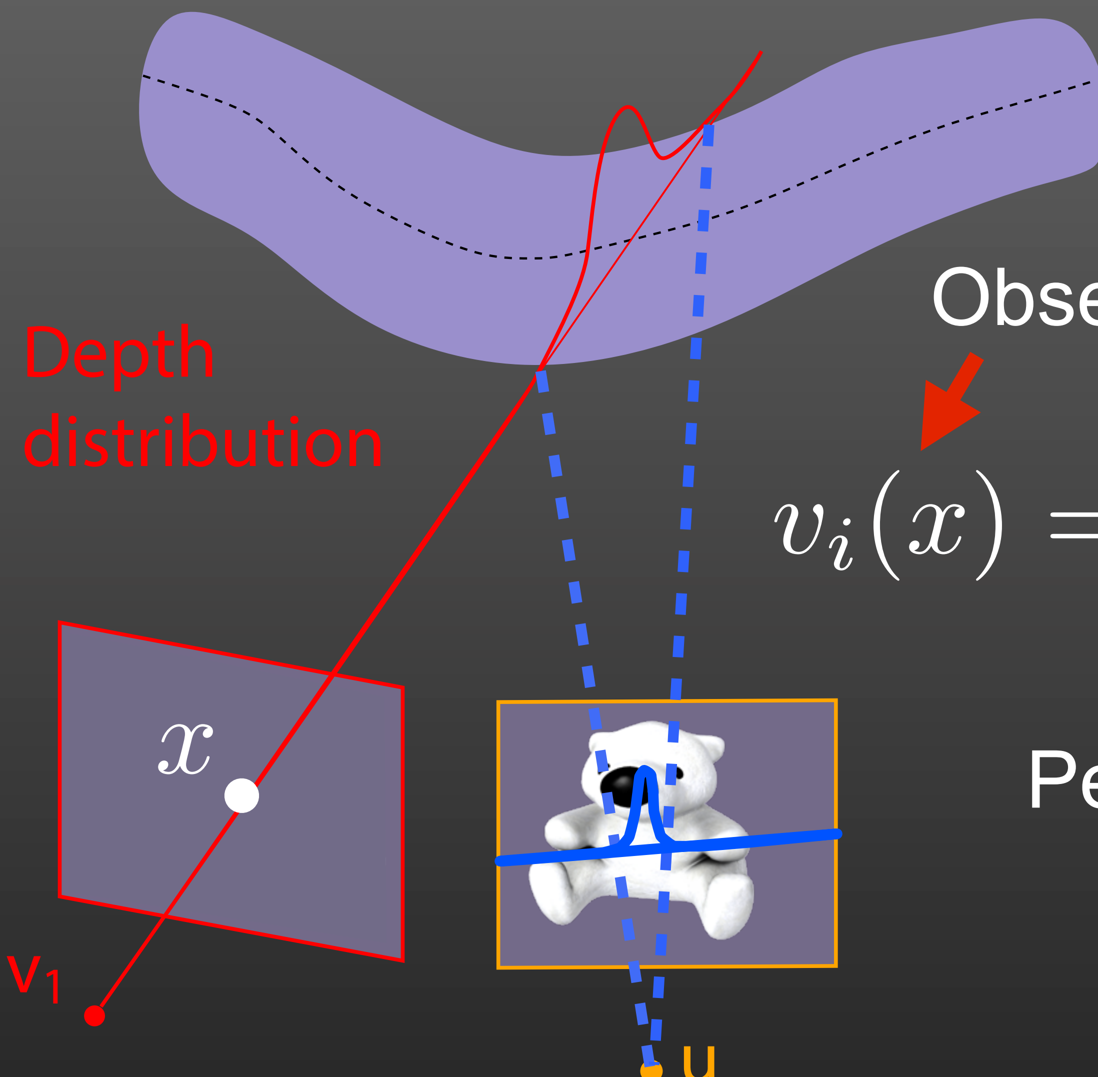

Input view

Target view

details in the paper

Observed image

Sensor noise

$$v_i(x) = \tilde{v}_i(x) + e_s(x) + e_g(x)$$

Perfect image

Geometric Noise

Support of the projected Gaussian depends on the angular deviation

Deducted weights

$$|det\ D\tau_i|^{-1} \ \left|\sigma_{z_i}^2 \left(\frac{\partial\left(u \circ \tau_i\right)}{\partial z_i}\right)^2\right|^{-1}$$

- Minimal angular deviation
- Physics based
- Resolution sensitivity

Deducted weights

$$\left|det\ D\tau_i\right|^{-1} \left|\sigma_{z_i}^2 \left(\frac{\partial\left(u \circ \tau_i\right)}{\partial z_i}\right)^2\right|^{-1}$$

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Weighting factor depends on

- ✚ correspondence confidence

Deducted weights

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- ➕ correspondence confidence

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- ✔ Minimal angular deviation
- ✔ Physics based
- ✔ Resolution sensitivity

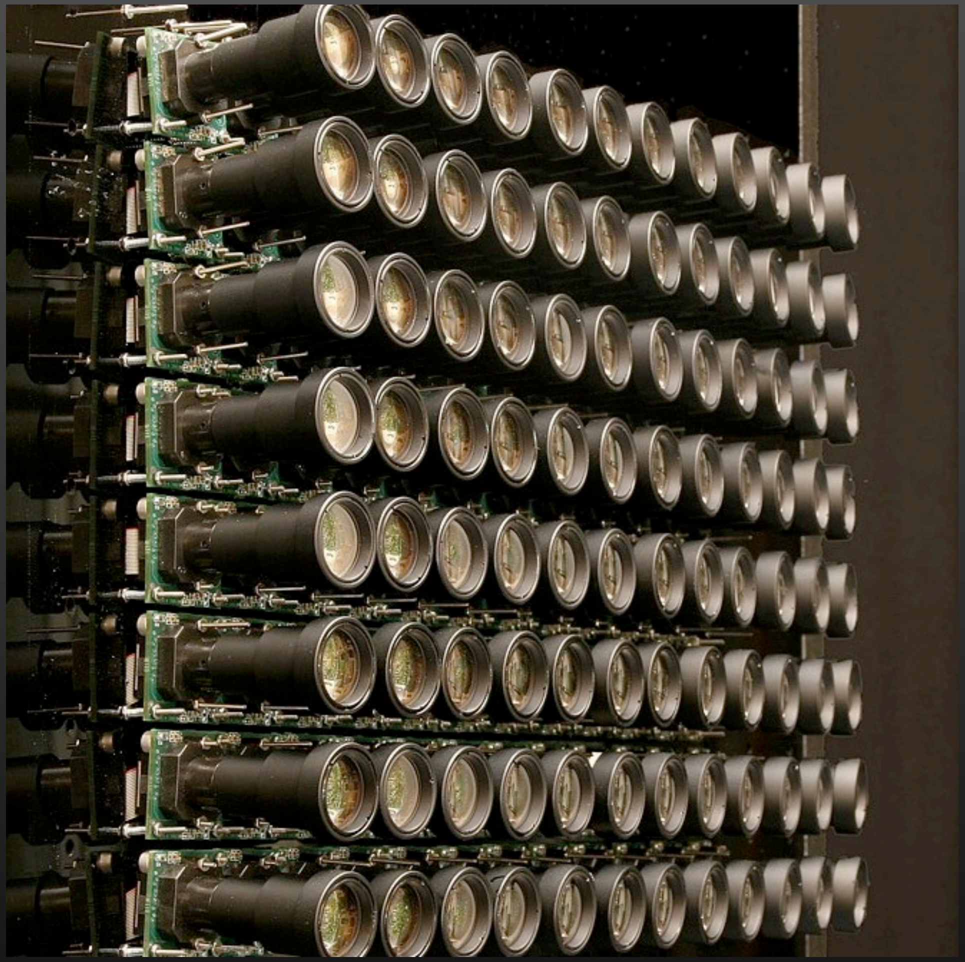
Weighting factor depends on

- ✚ correspondence confidence
- ✚ image content (color gradient along epipolar line)

Experiments

Implementation of a simplified camera configuration

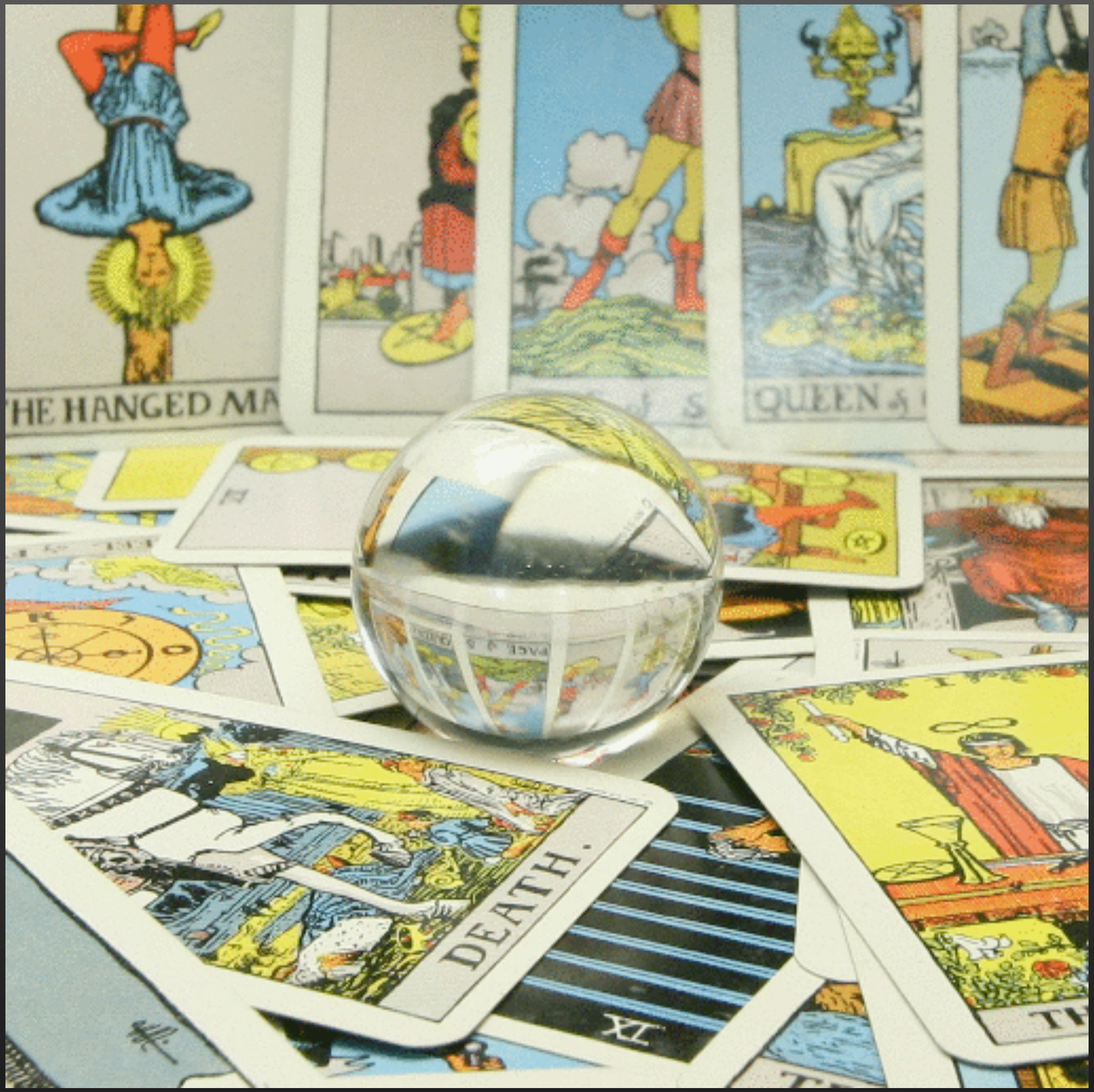
4D Light Field



Stanford multi-camera array

The (New) Stanford Light Field Archive

Tarot

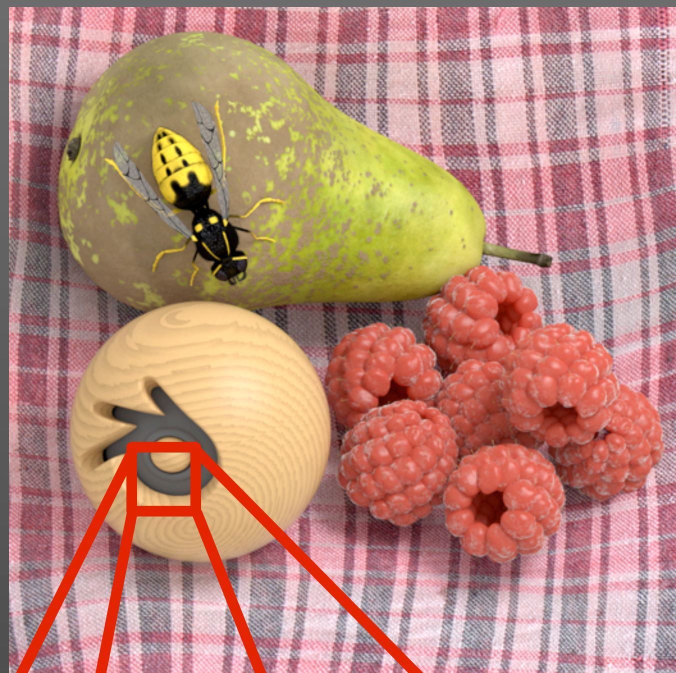


Truck

HCI Lightfield Dataset

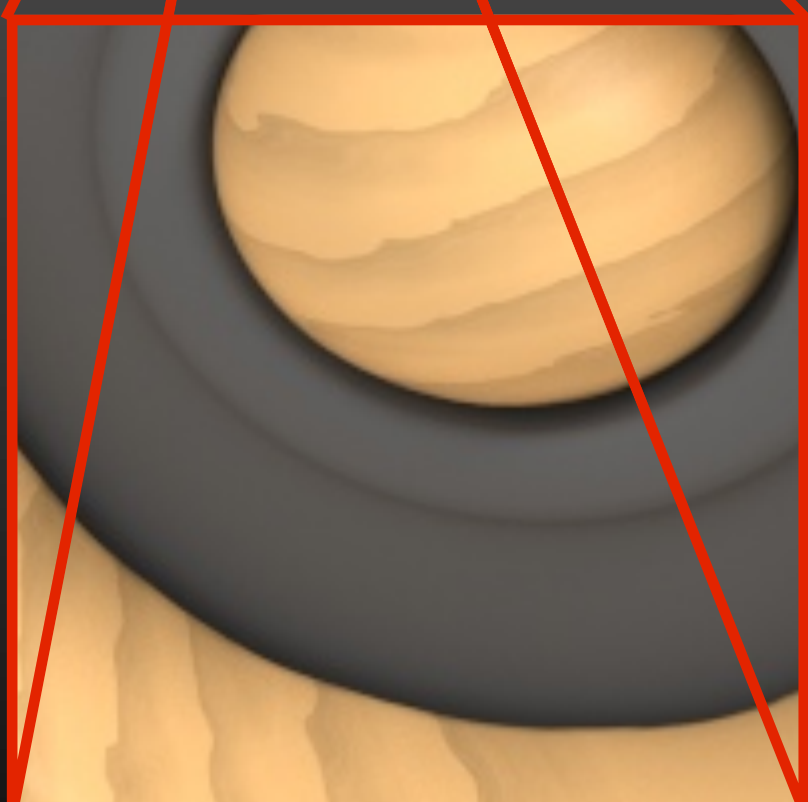
Maria

Still Life



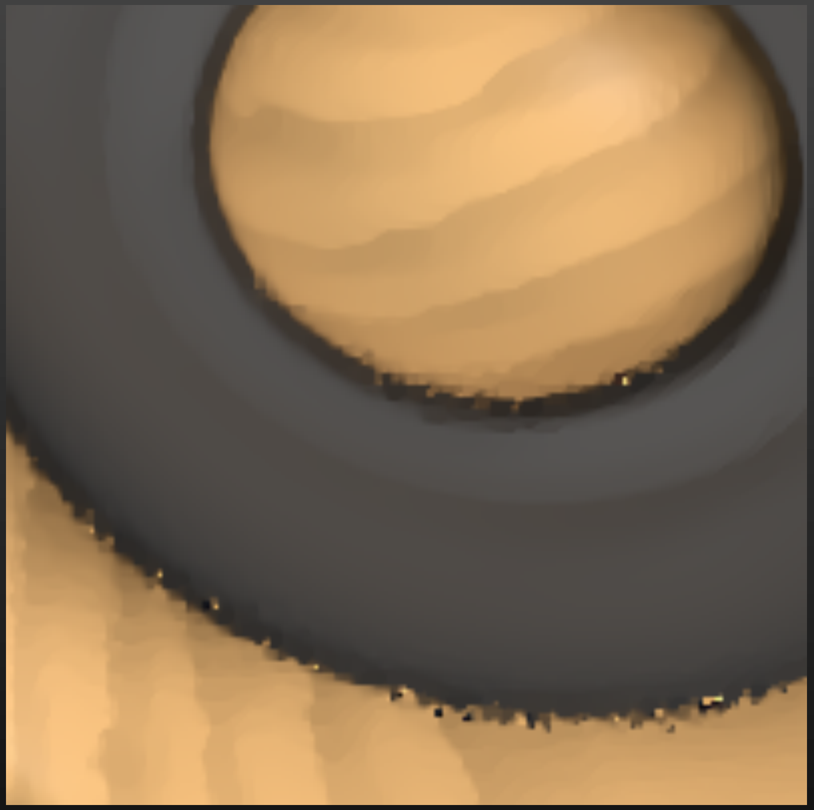
Results

Ground truth

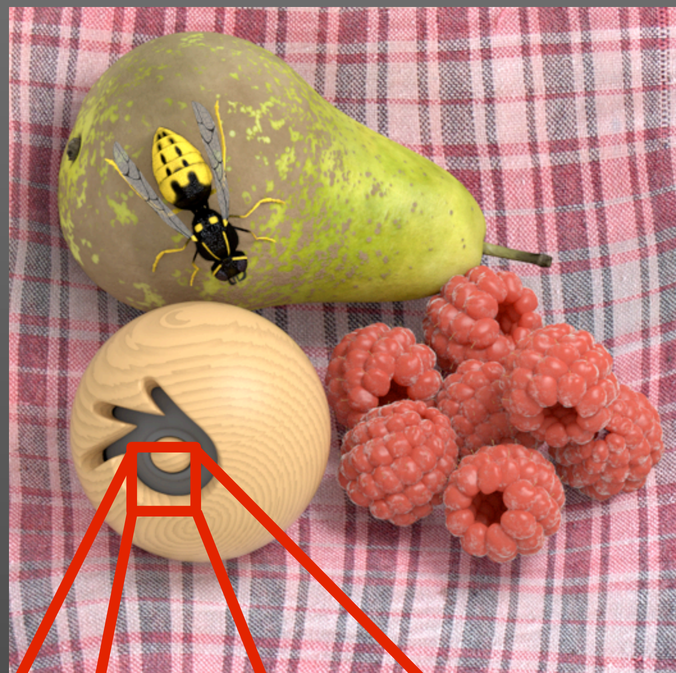


Previous method

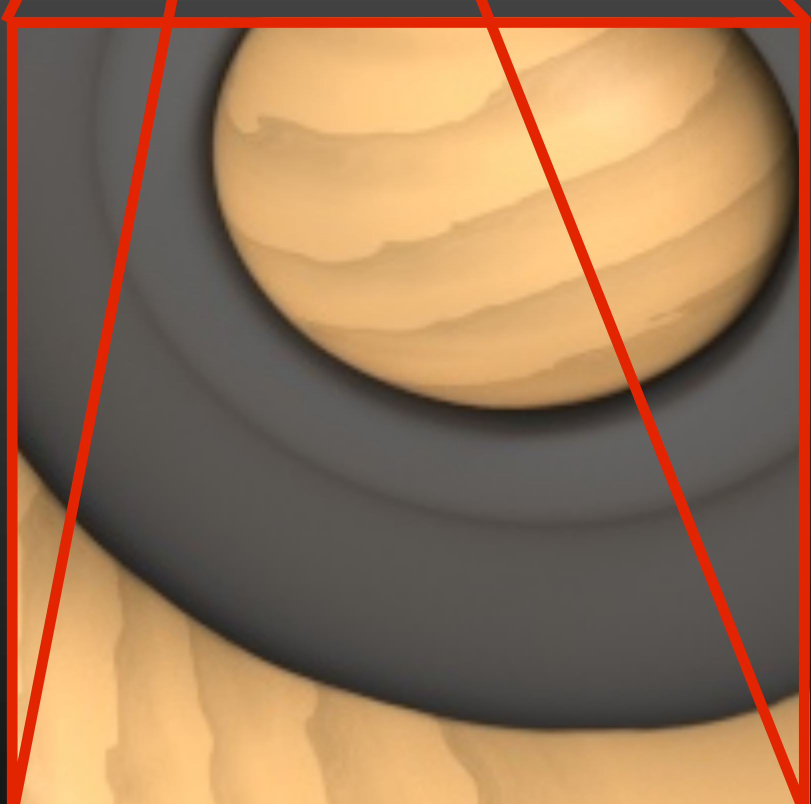
Wanner and Goldluecke ECCV 2012



Results



Ground truth



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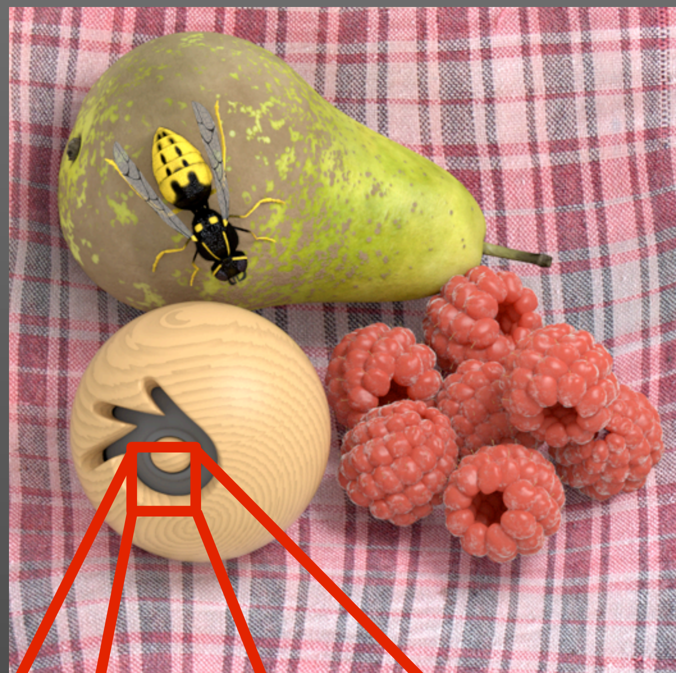

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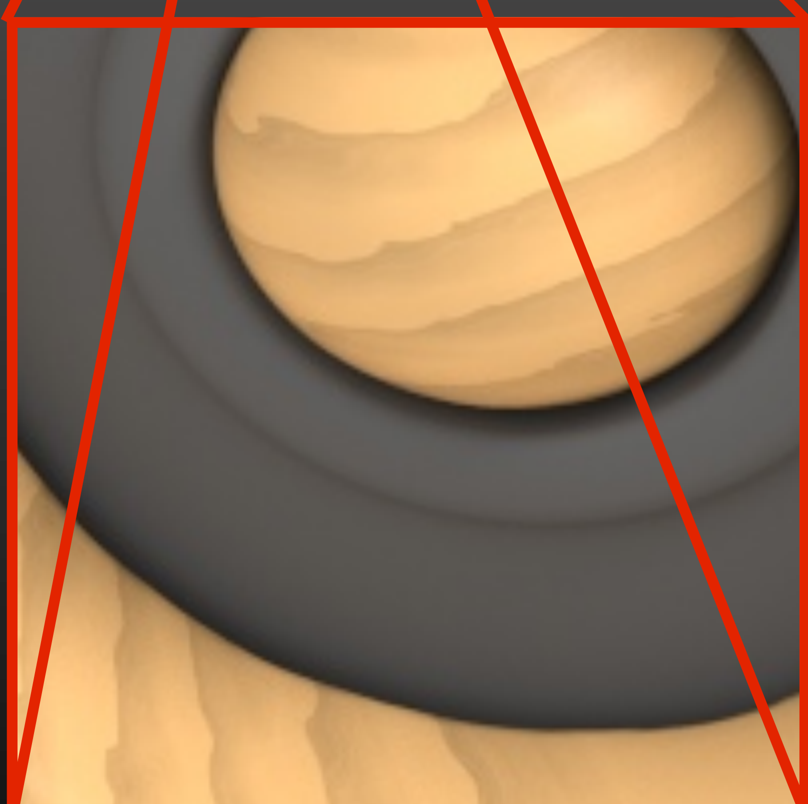

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Proposed method

What is happening?

Better selection of the contributing views based on :

- View distance
- color gradient aligned with view displacement

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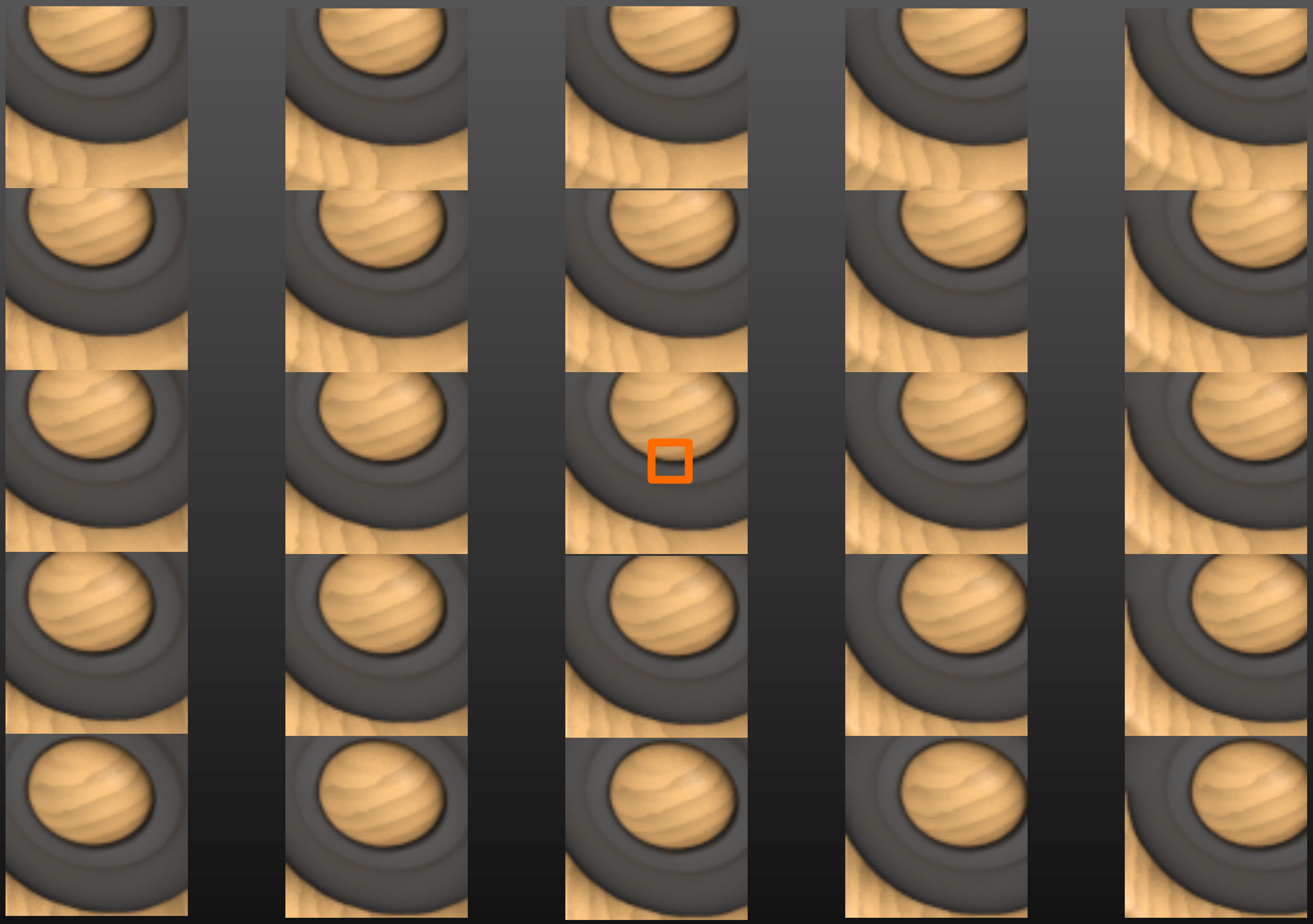

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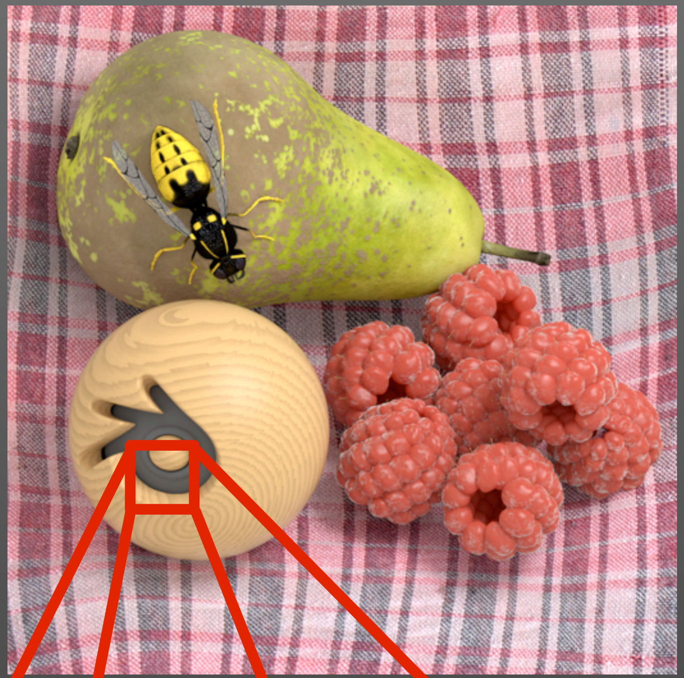

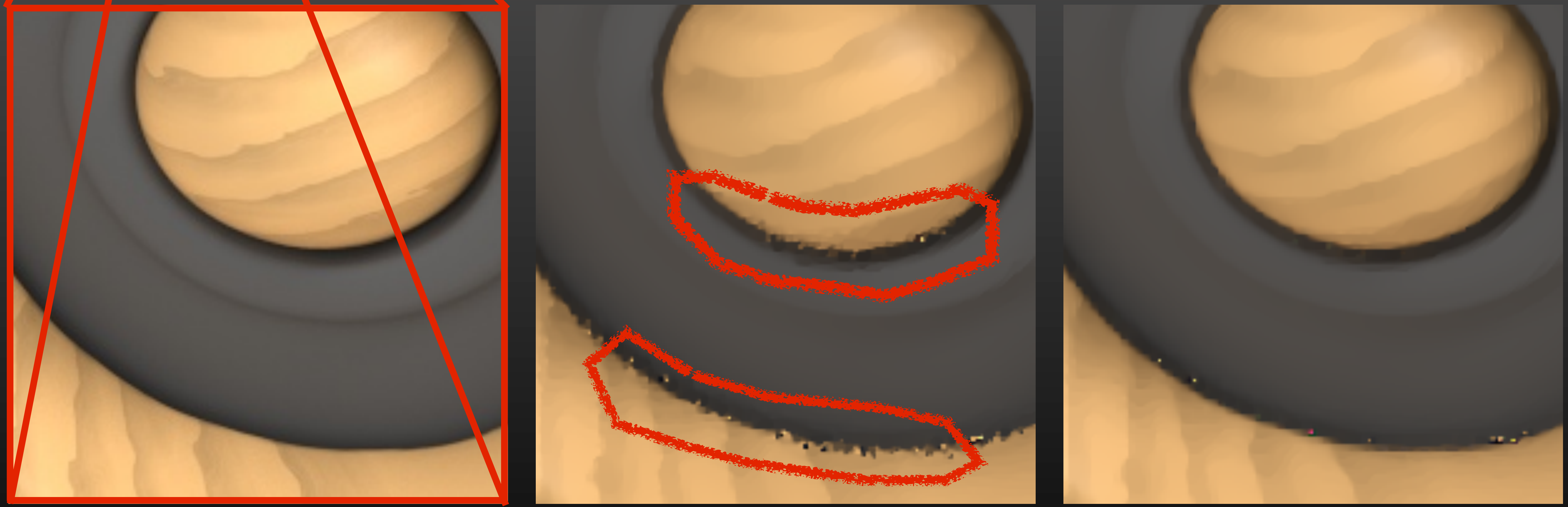

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Status and future work

- Use of geometric proxies ✓
- Unstructured input ✓
- Epipole consistency ✓
- Equivalent ray consistency ✓
- Minimal angular deviation ✓
- Resolution sensitivity ✓
- Formal deduction ✓
- Physics-based parameters ✓
- Continuity ✗
- Real-time ✗

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Conclusion

New generative model for IBR

Unify current knowledge

Improve results

Code available as part of **cocolib** library

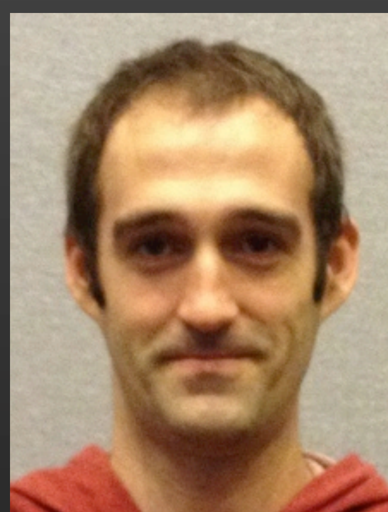
http://sourceforge.net/projects/cocolib/

Take home messages

Bayesian formulation:
  Use physically-sound parameters!

Uncertainty is helpful:
  Don't throw away your covariance matrices!

Bayesian View Synthesis and Image-Based Rendering Principles



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CVPR 2014

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ACTION 3Ds