Exposing Photo Manipulation with Geometric Inconsistencies

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Collaborators

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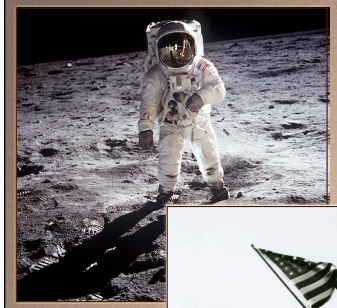
Communication by Images



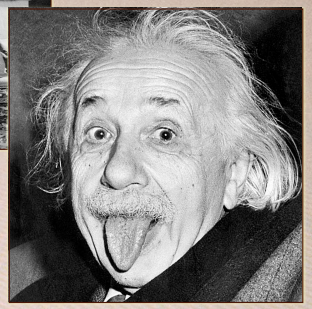


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Image Manipulation

Iranian missile test, 2008

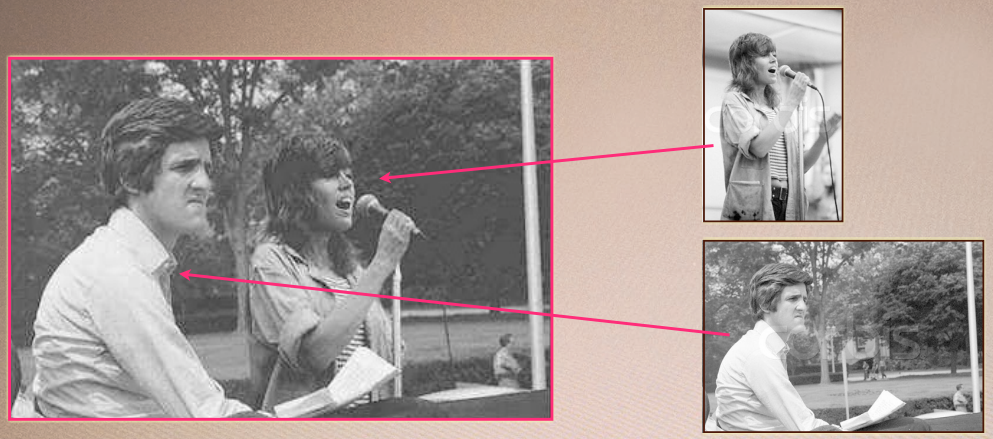
3

Image Manipulation

Economist manipulates image of Obama, 2010

4

Image Manipulation



Fabricated image of John Kerry and Jane Fonda, 2004

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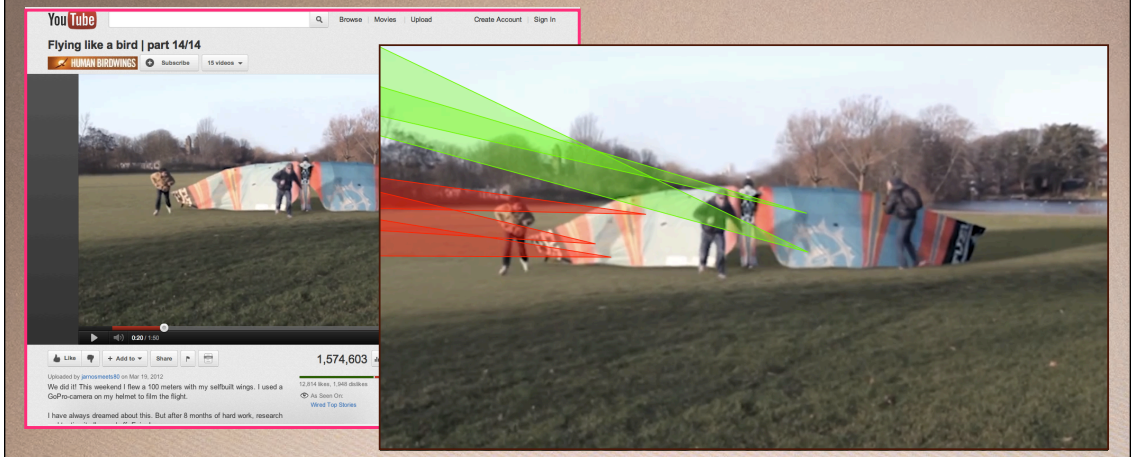
Video Manipulation

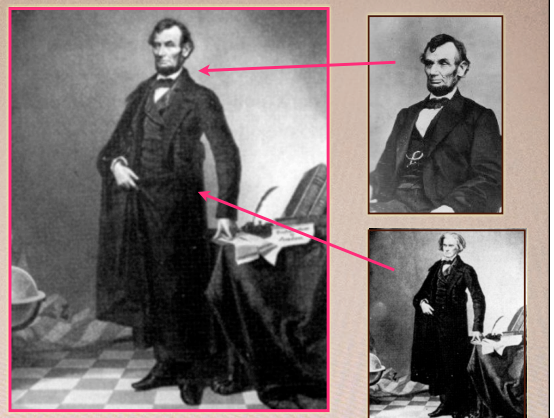


Flying Birdman Hoax, 2012

6

Historical Image Manipulation

- Image manipulation as old as photography
- Primitive techniques work surprisingly well



Library of Congress archive photo of Abraham Lincoln 1826

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Historical Image Manipulation

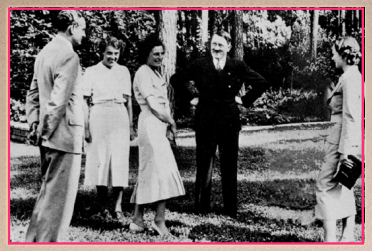

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Image Forensics

- Detect forgeries
  - Detect signs of manipulation
    - **Prove image was modified in some way**
  - Cannot *prove* an image *unmodified*
- Suite of detection tools
  - Individual methods can be countered
  - Individual tools may not apply in all cases
  - Each additional method makes forgery harder

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Advantage: Forgers

- People:
  - Good at understanding scene content
  - Poor at noticing many types of inconsistencies
- Simple manipulation methods work well
- New manipulation methods being developed

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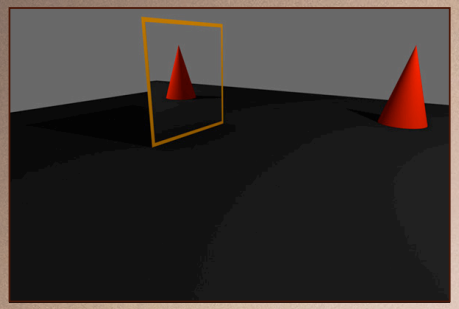
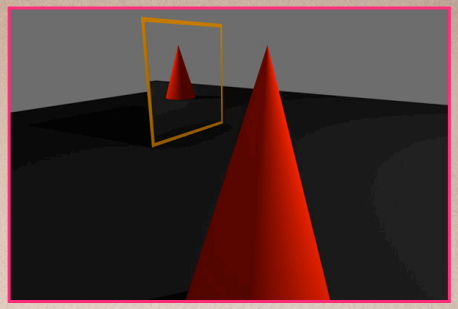
Example Inconsistency



Selected as correct: 62.1%



Selected as correct: 50.1%

N = 20; RT = 7.6s

Farid and Bravo 2010

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Advantage: Forgers

- People:
  - Good at understanding scene content
  - Poor at noticing many types of inconsistencies
- Simple manipulation methods work well
- New manipulation methods being developed
  - **Something called "Photoshop" is a particular difficulty...**

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Image Forensics

- **Low-level methods**
  - Examples:
    - Quantization tables
    - Chromatic aberration
    - Compression artifacts
  - Not tied to scene content
    - Easy to apply
    - Easy to fool (informed attacker)
    - Not robust to common operations
- **Geometric methods**
  - Content inconsistencies
  - Require human annotation
    - Computer analysis
  - Examples:
    - Shadows
    - Lighting
    - Reflections

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Geometric Image Forensics

- **Not same as Computer Vision**
  - **User involved in loop**
  - **Only looking for inconsistencies only**
    - **Don't need to fully extract scene content**

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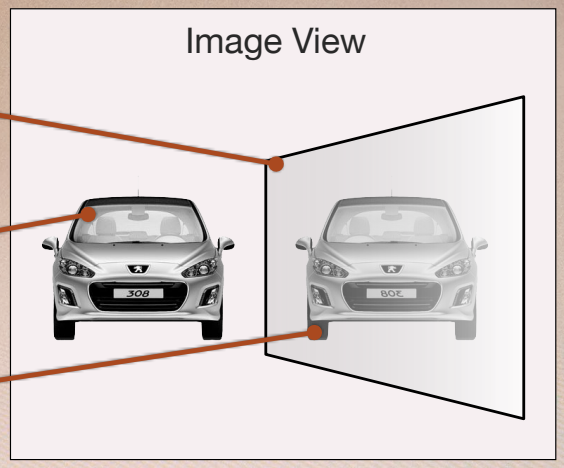
Basic Mirror Geometry

Linear perspective image



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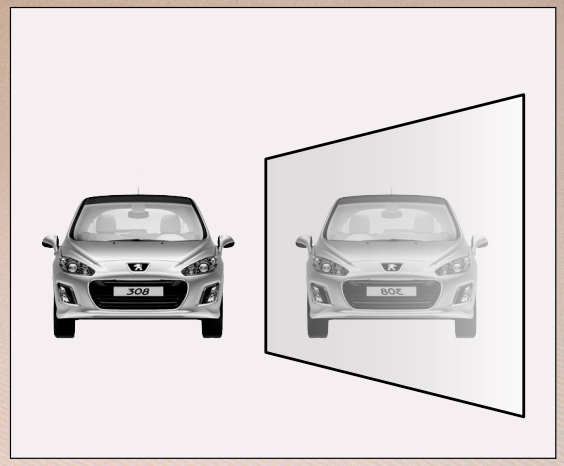
Basic Mirror Geometry



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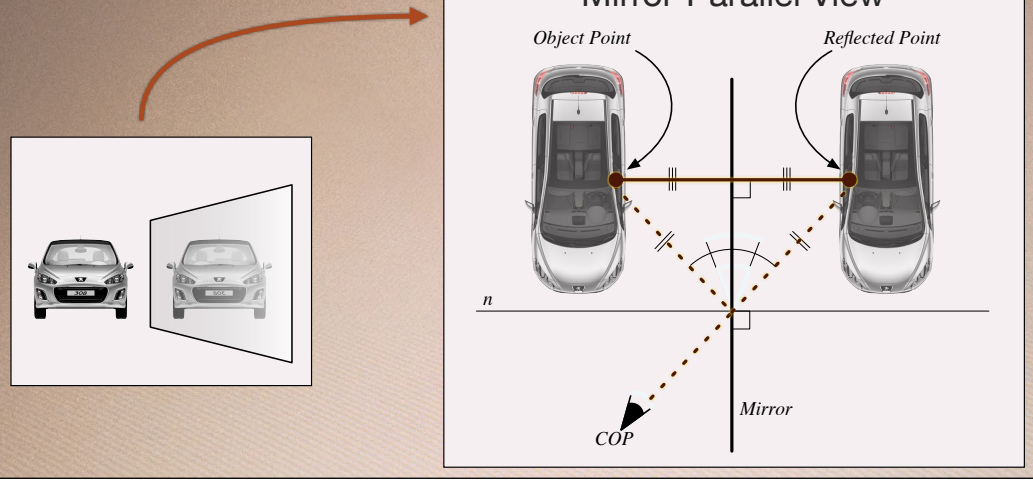
Basic Mirror Geometry



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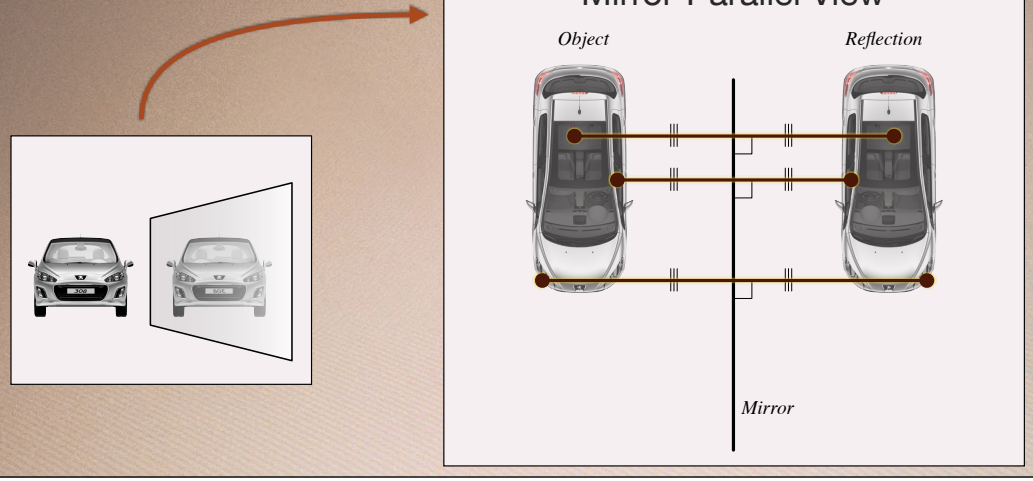
Basic Mirror Geometry



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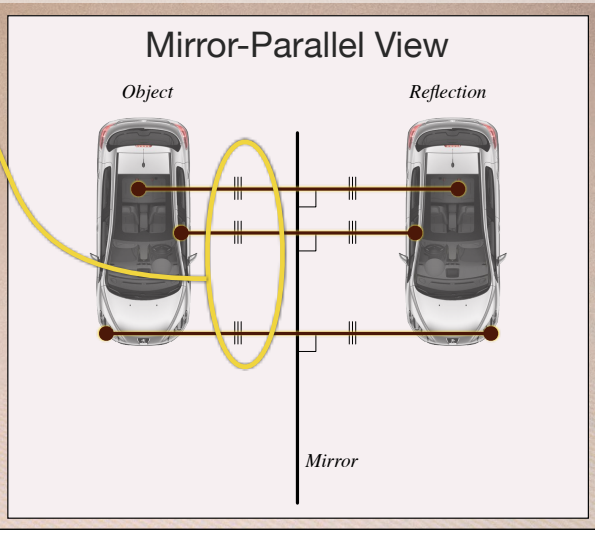
Basic Mirror Geometry

Bundle of parallel lines

In original image they must converge to a common vanishing point.

(Possibly at infinity)



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Reflection Vanishing Point

Real Photograph

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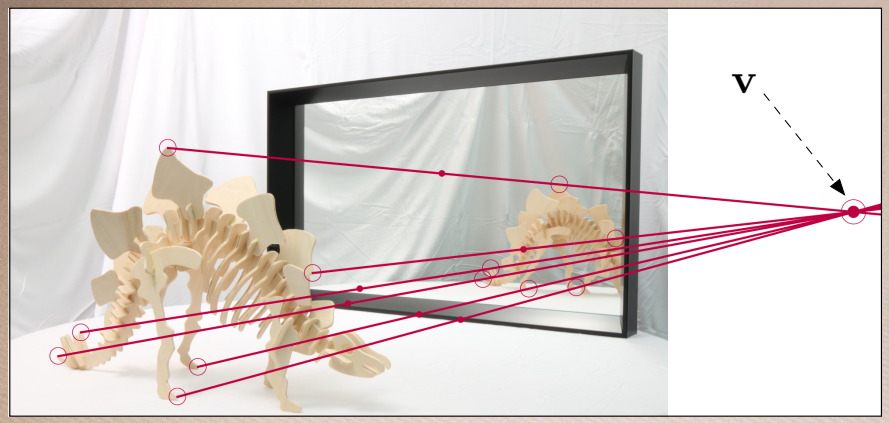
Reflection Vanishing Point

Real Photograph



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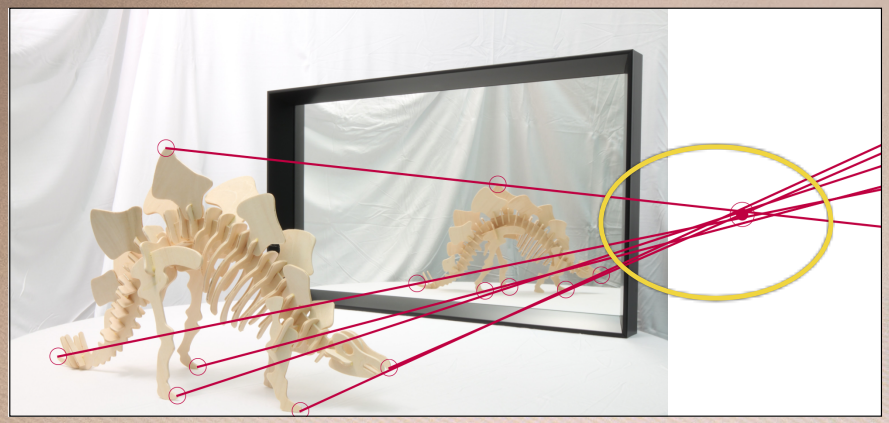
Reflection Vanishing Point

Altered Photograph

22

Reflection Vanishing Point

Altered Photograph



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Examples

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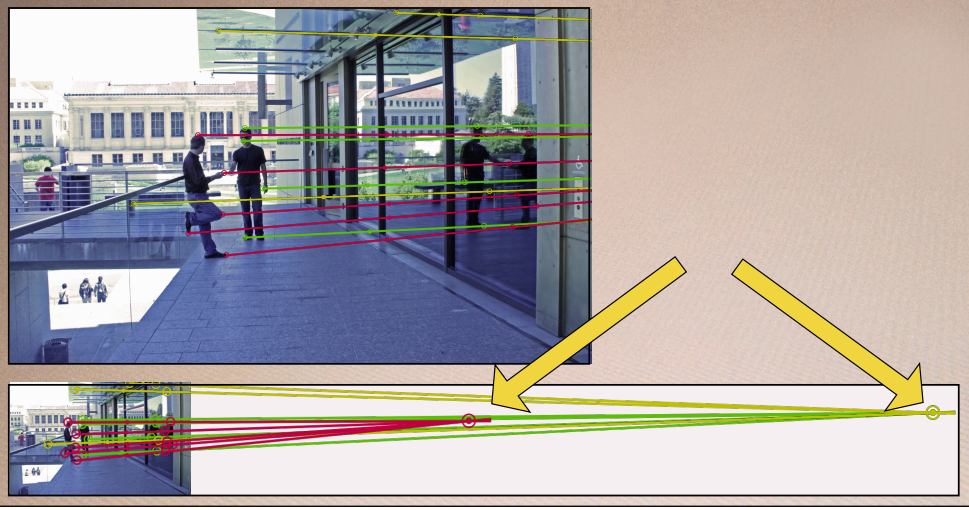
Examples



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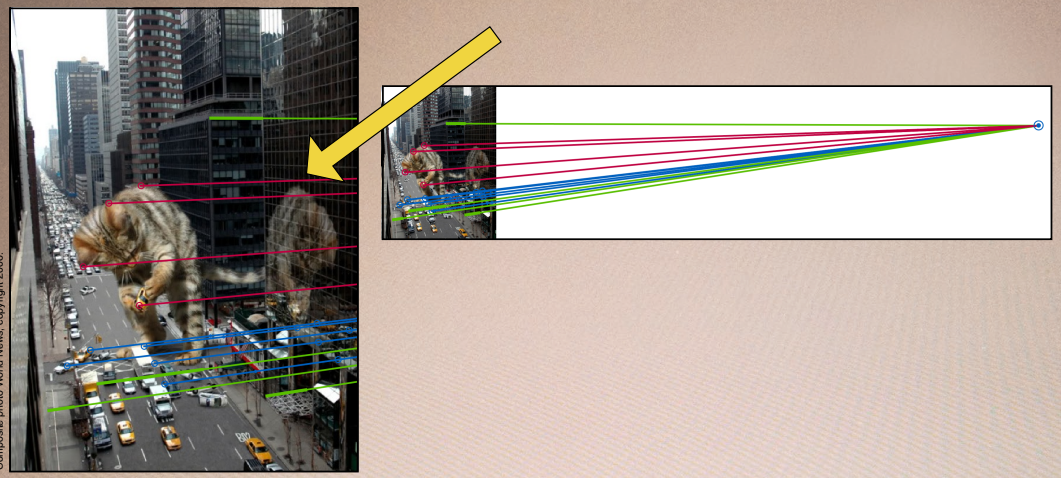
Examples

Composite photo World News, copyright 2006.

26

Examples



Composite photo World News, copyright 2006.

27

Examples

Photo by Alexi Lubomirski, "The Saint and the Sinner", copyright 2009.

28

Examples

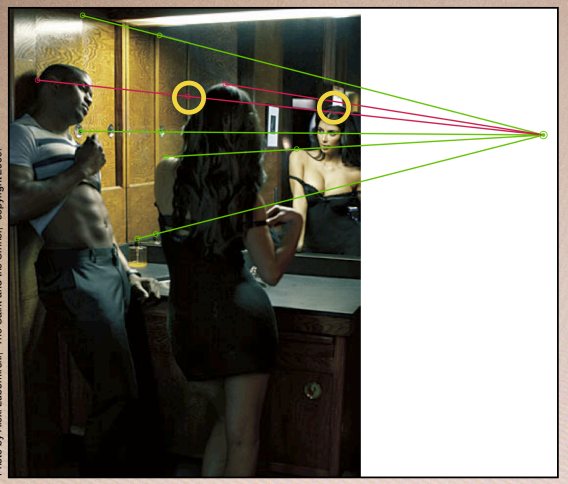


Photo by Alexi Lubomirski, "The Saint and the Sinner," copyright 2009.

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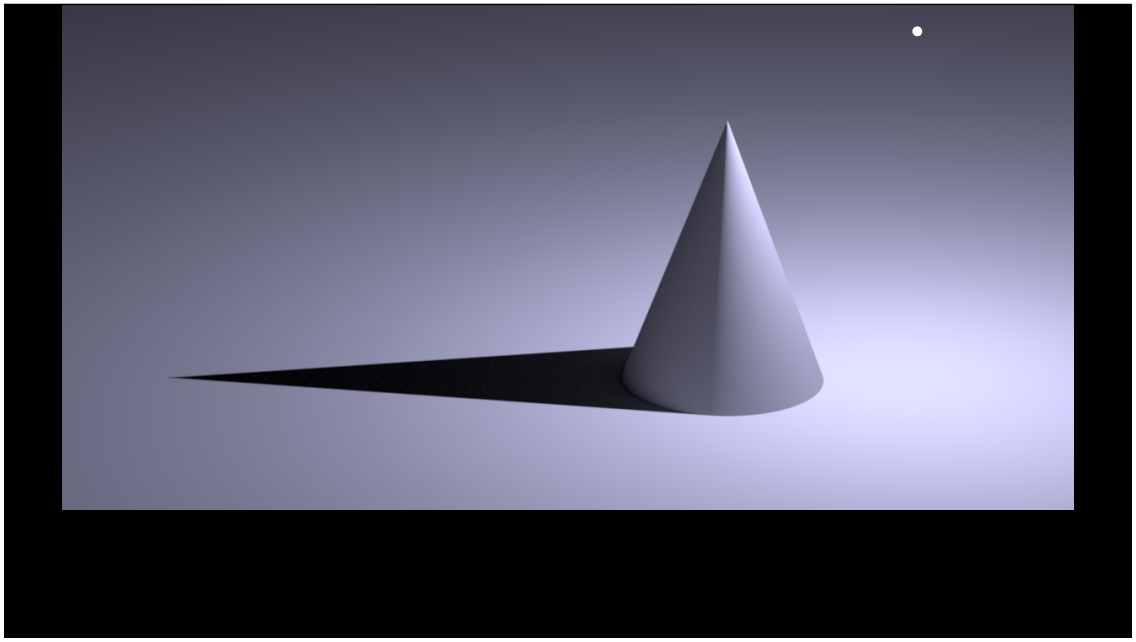

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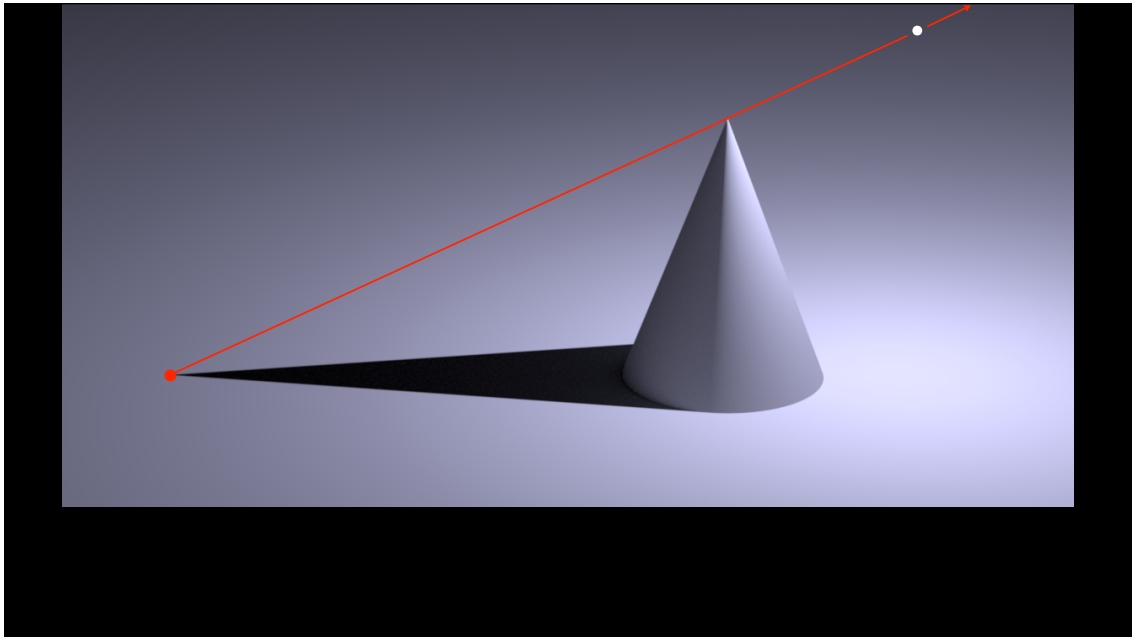

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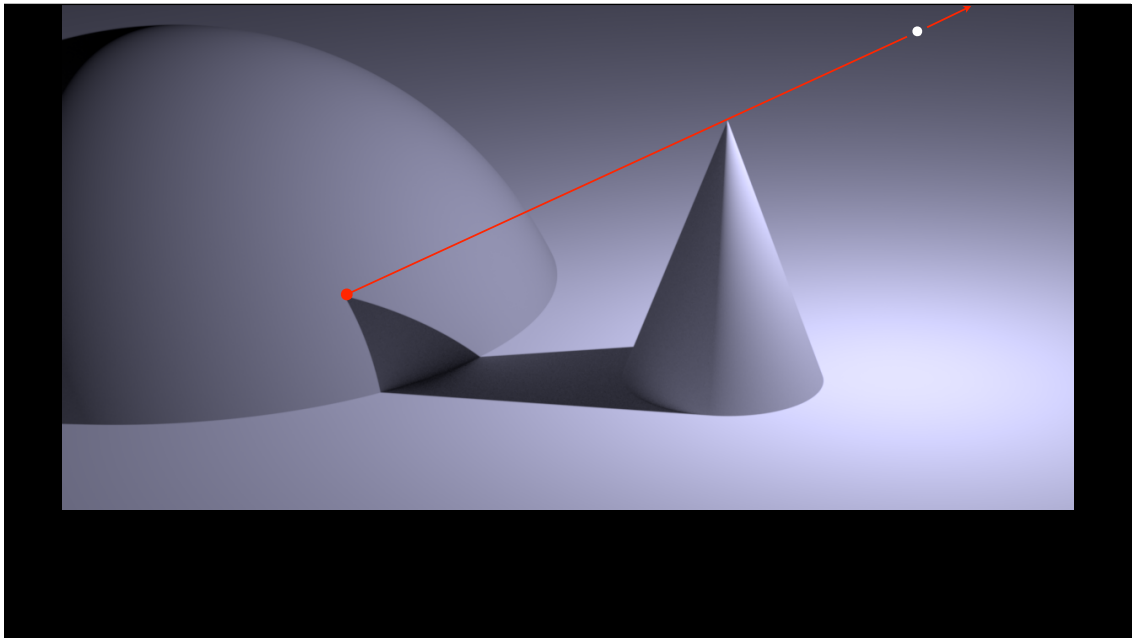

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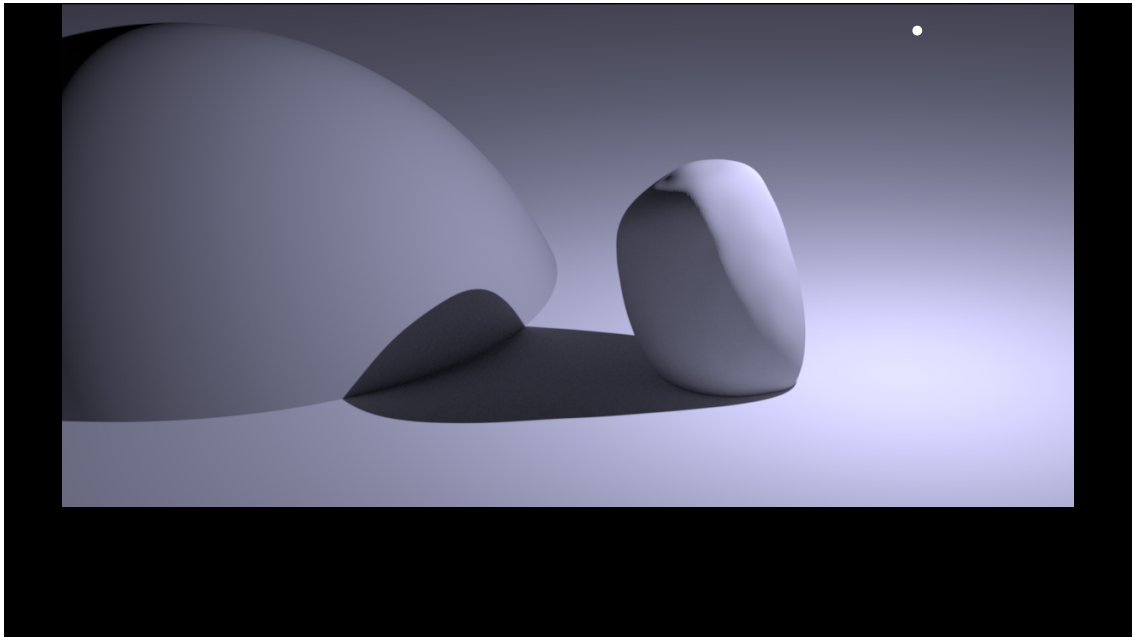

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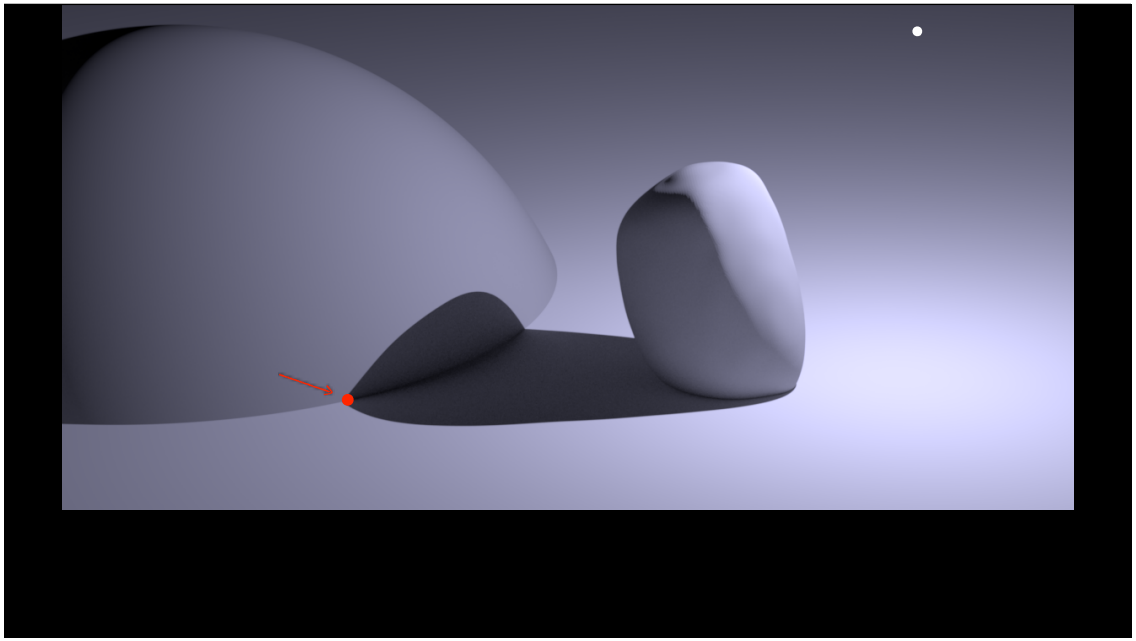

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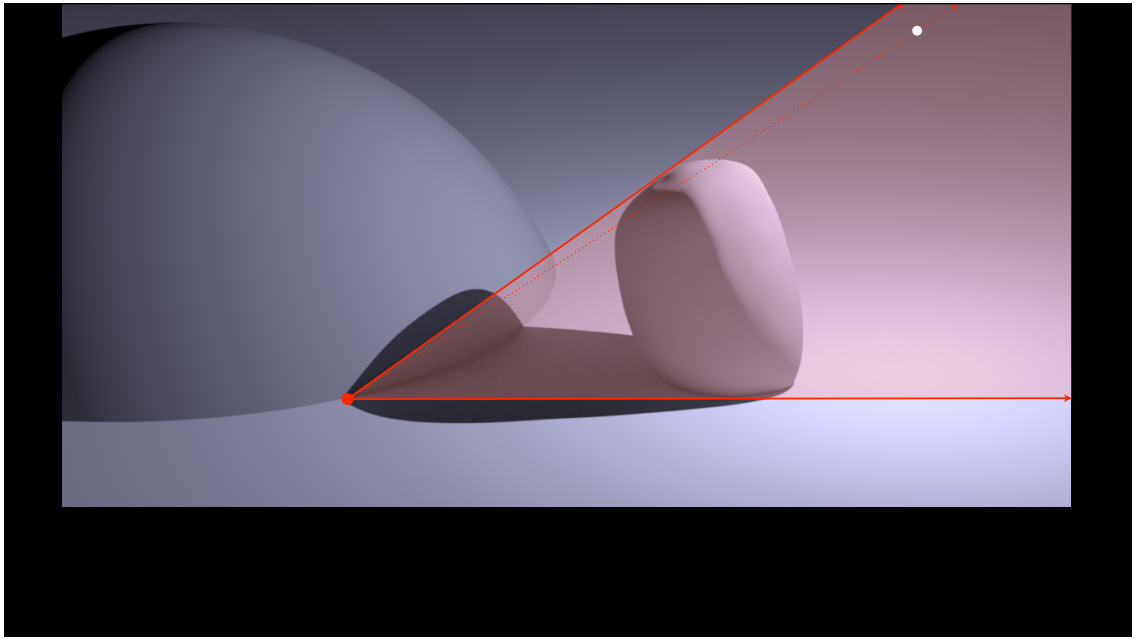

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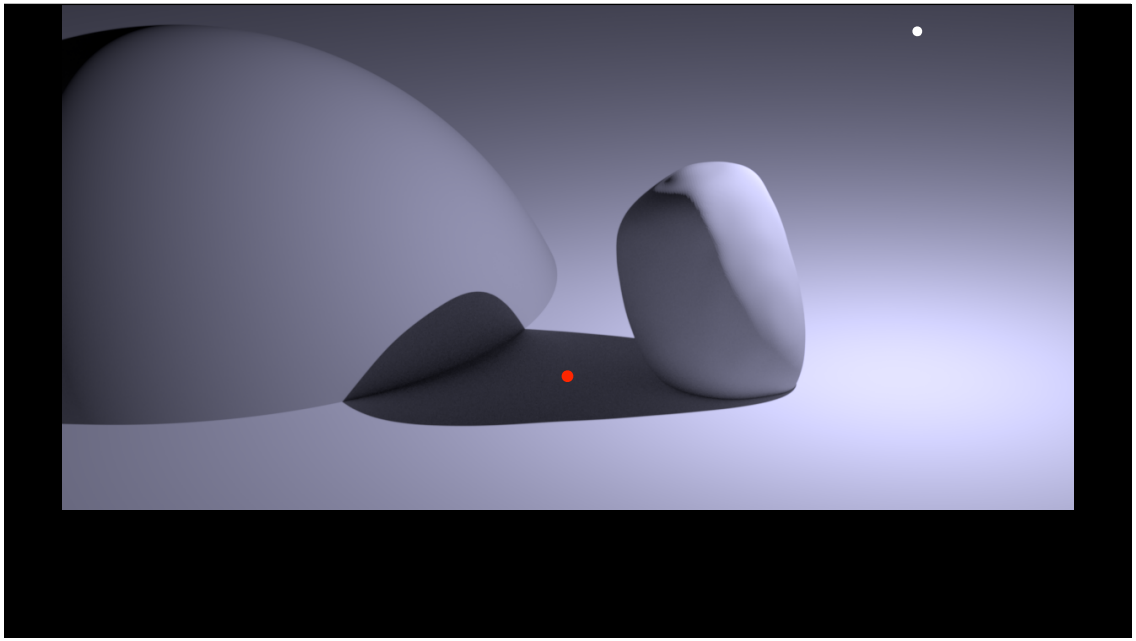

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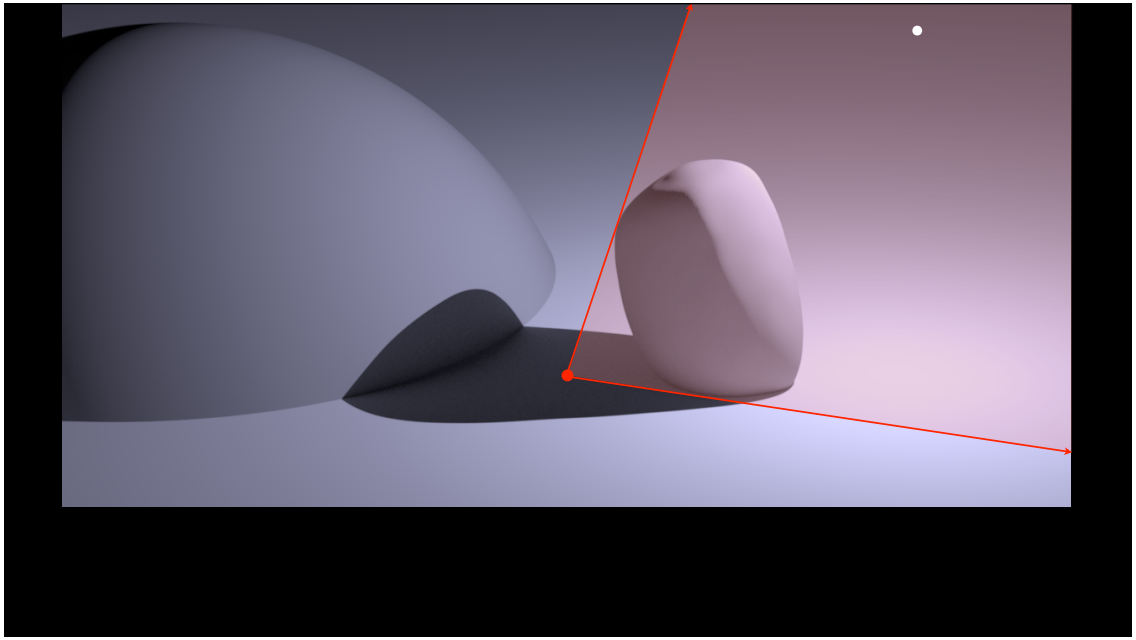

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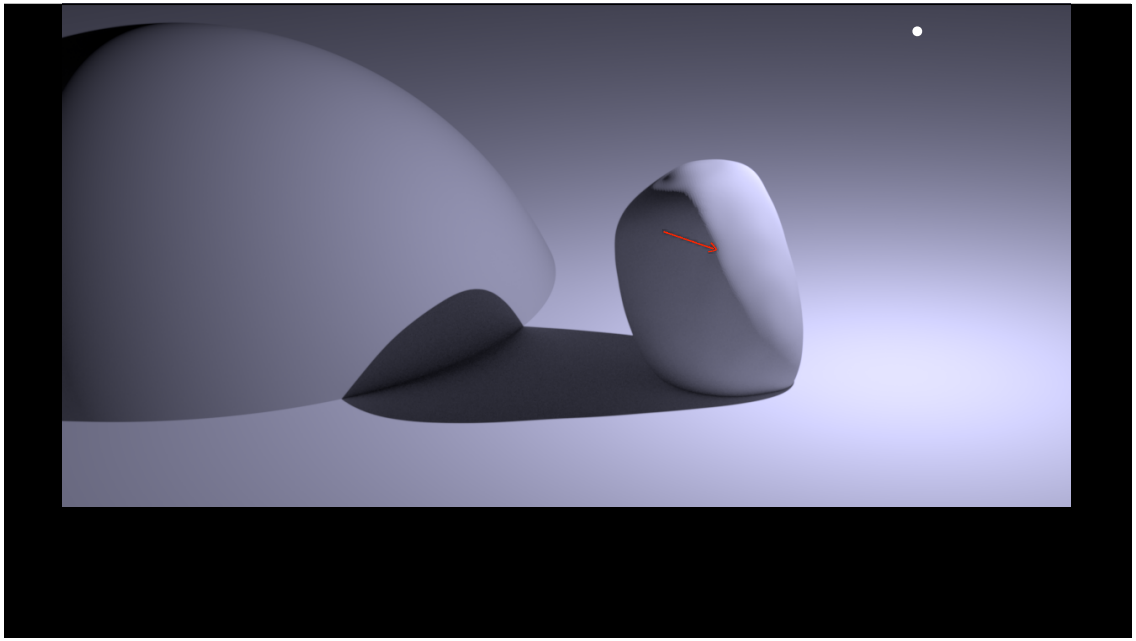

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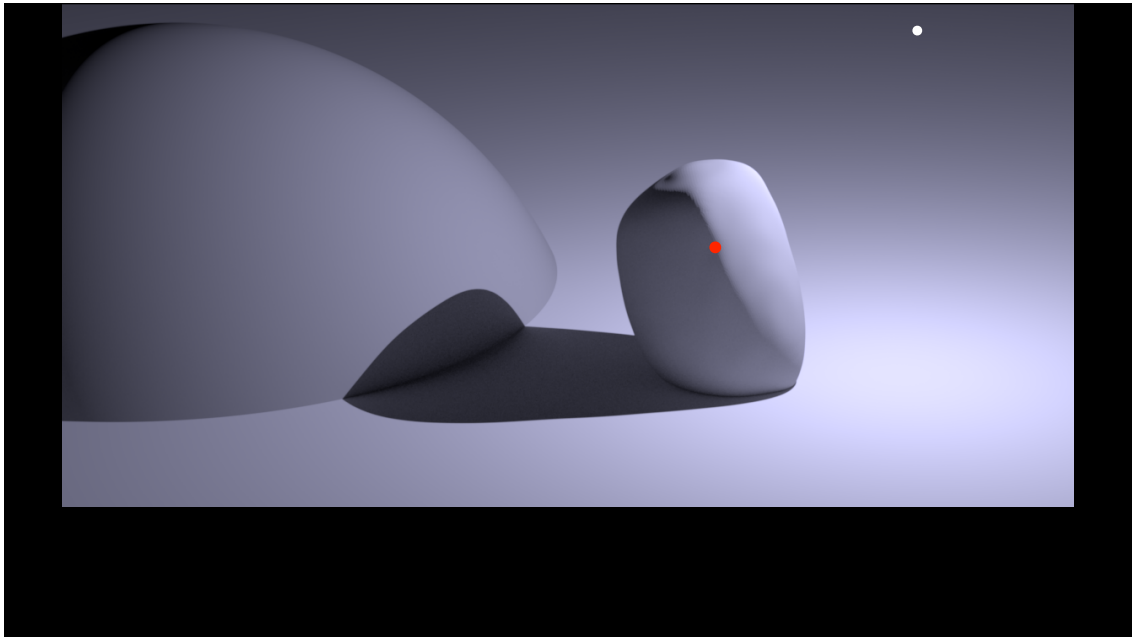

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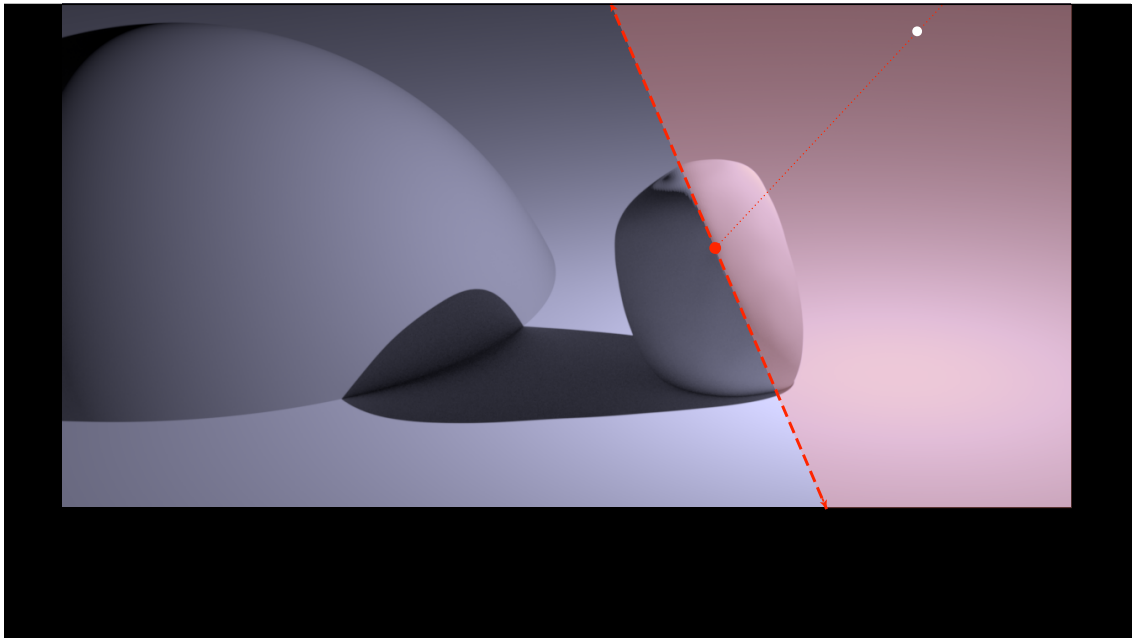

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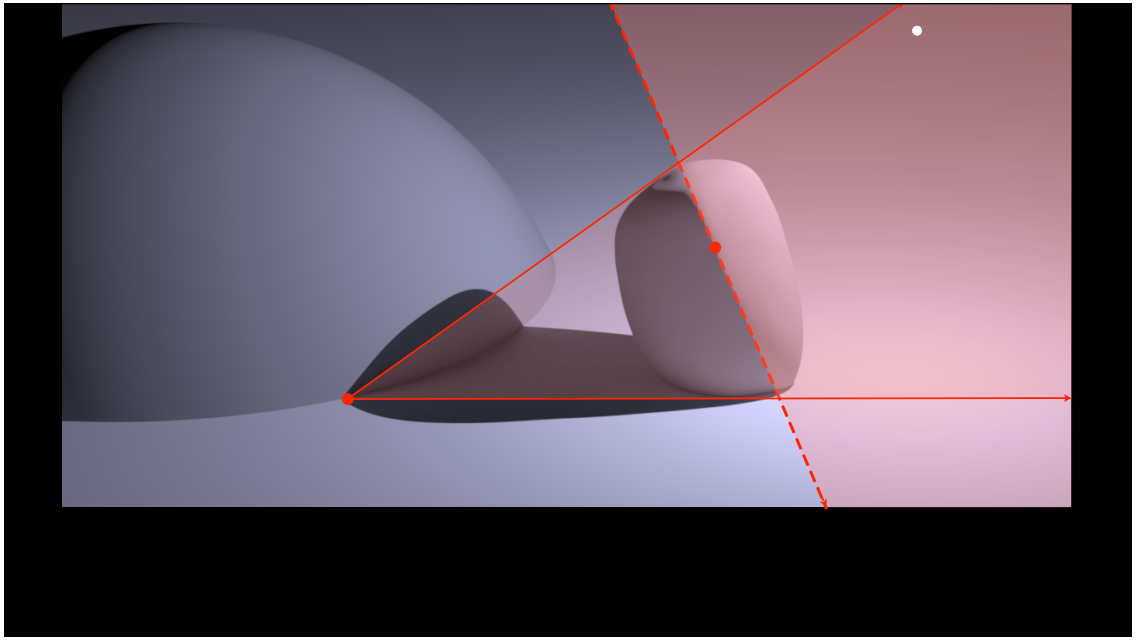

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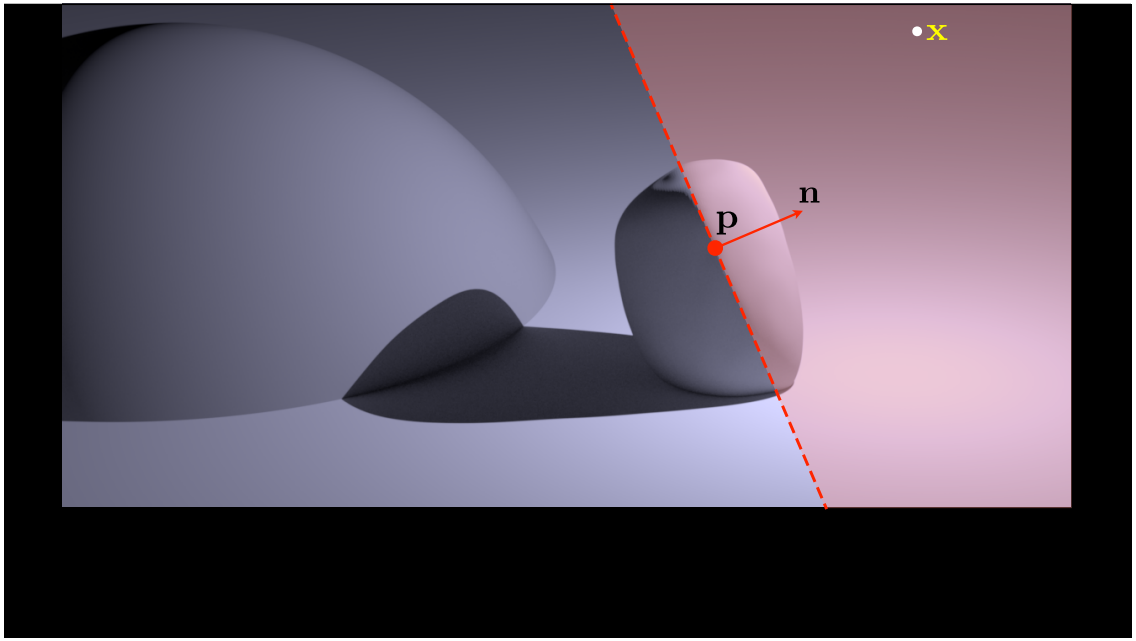

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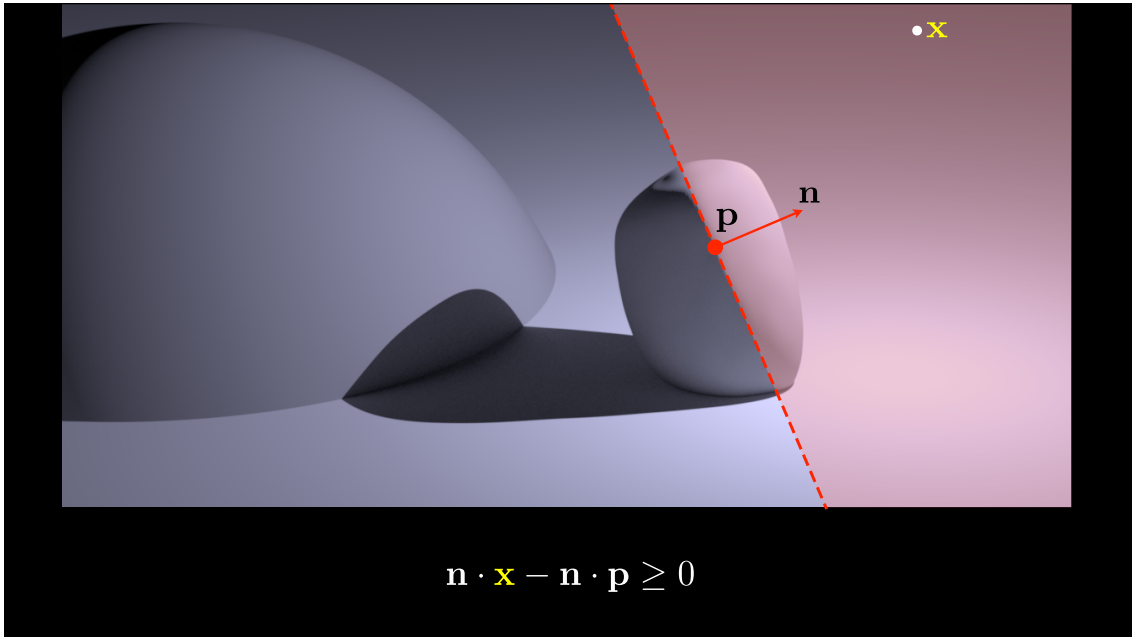
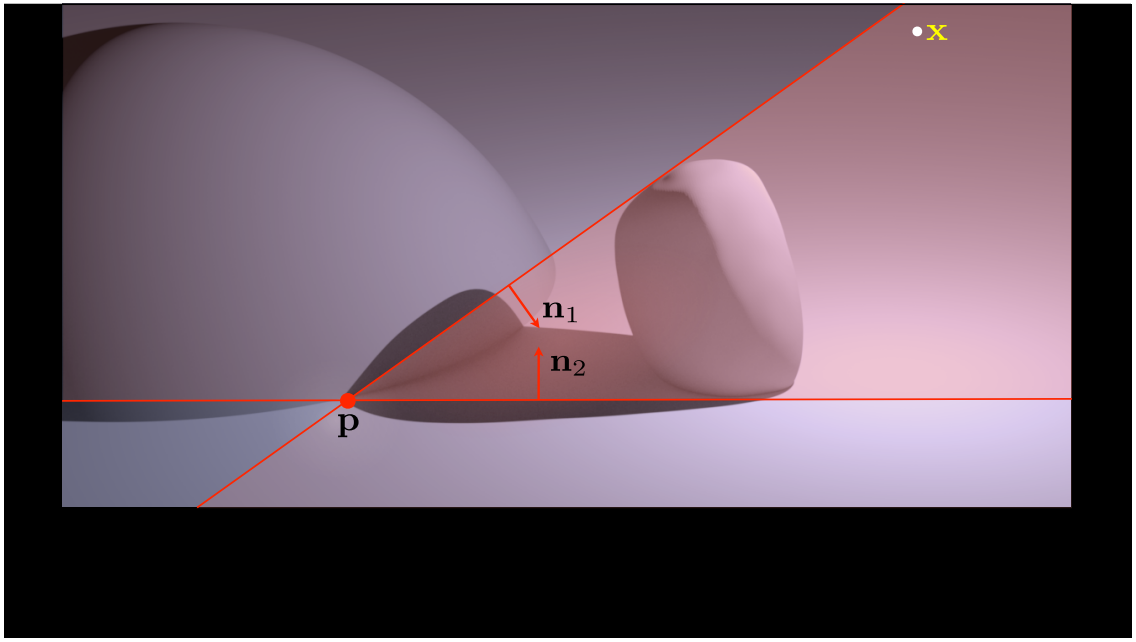
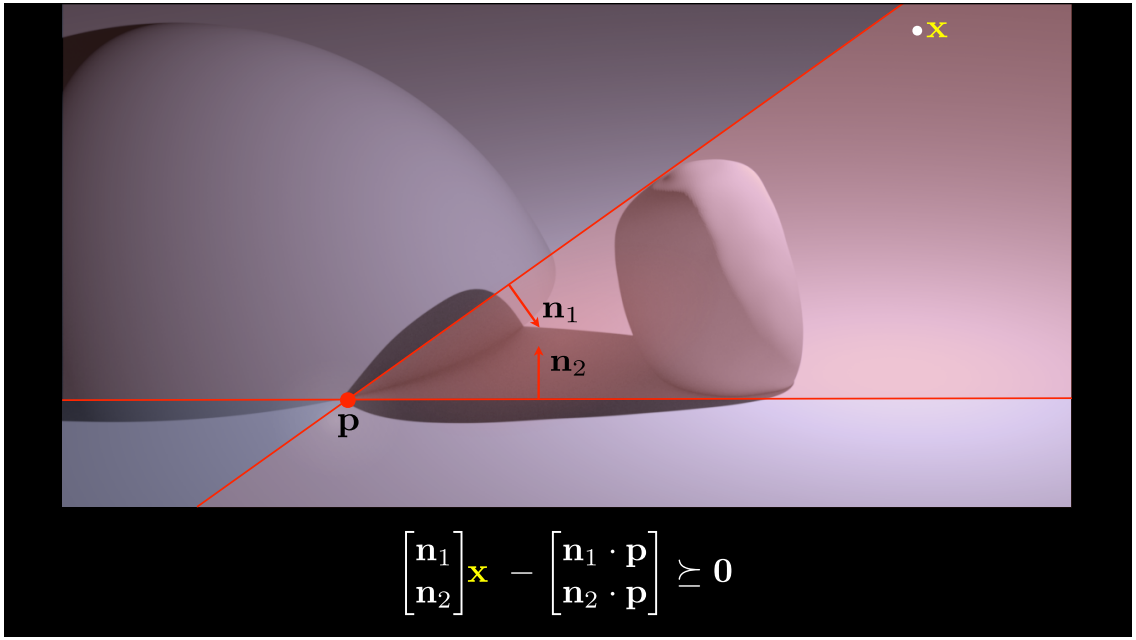

x
n
p
$\mathbf{n} \cdot \mathbf{x} - \mathbf{n} \cdot \mathbf{p} \geq 0$

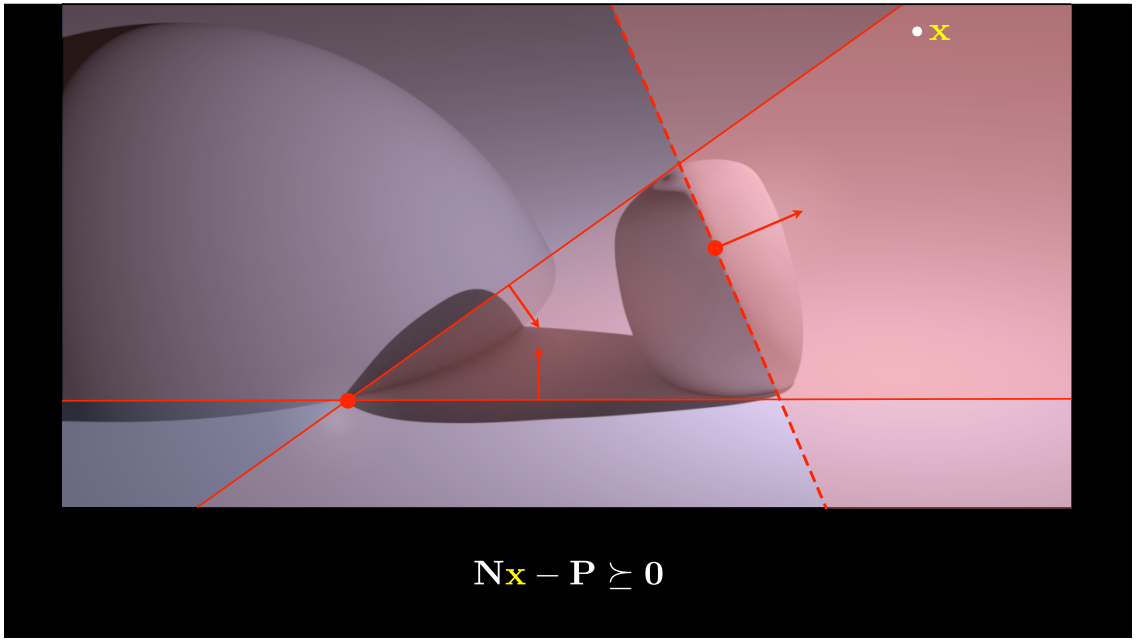
43


x
$\mathbf{n}_1$
$\mathbf{n}_2$
p

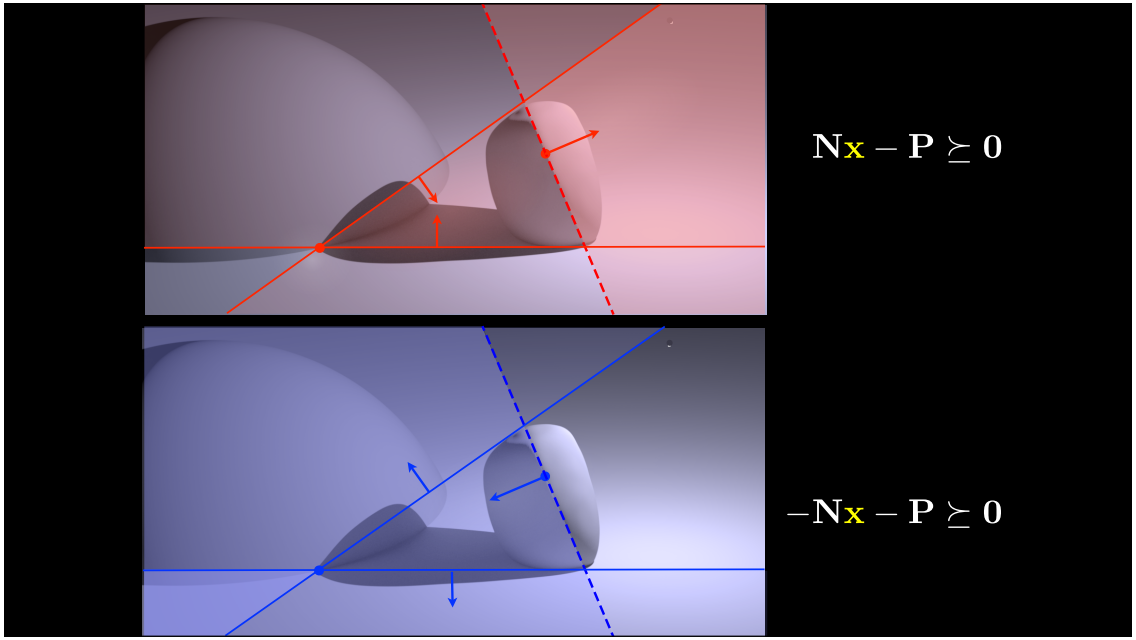
44


x
$\mathbf{n}_1$
$\mathbf{n}_2$
p
$\begin{bmatrix}\mathbf{n}_1\\ \mathbf{n}_2\end{bmatrix}\mathbf{x} - \begin{bmatrix}\mathbf{n}_1 \cdot \mathbf{p}\\ \mathbf{n}_2 \cdot \mathbf{p}\end{bmatrix} \succeq \mathbf{0}$

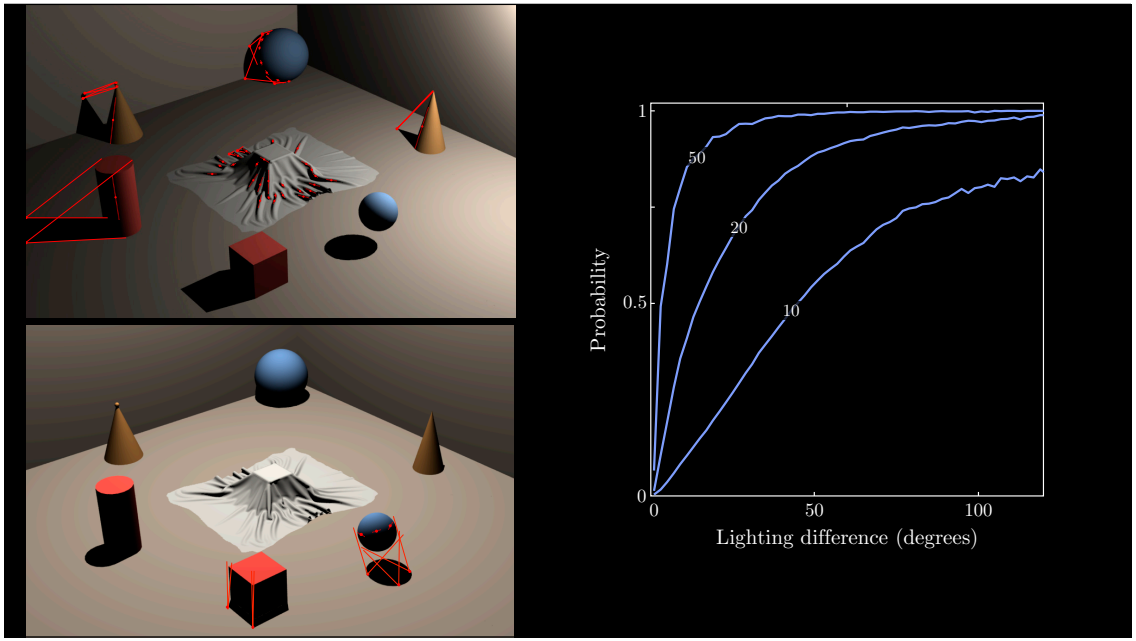
45


x
$\mathbf{N}\mathbf{x} - \mathbf{P} \succeq \mathbf{0}$

46

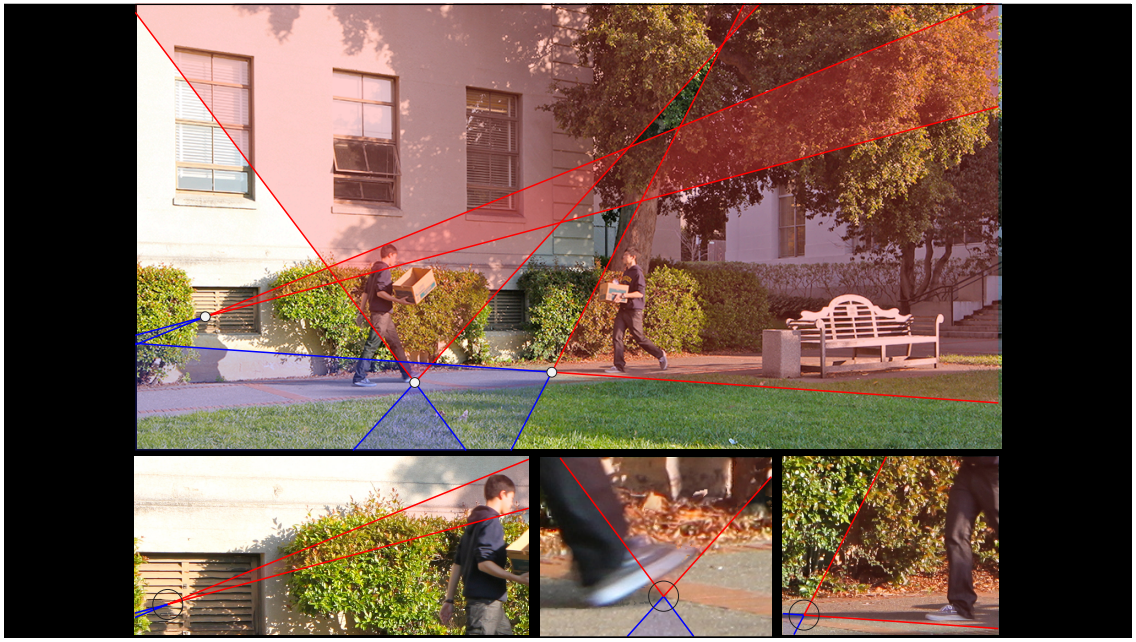

$\mathbf{Nx} - \mathbf{P} \succeq \mathbf{0}$
$-\mathbf{Nx} - \mathbf{P} \succeq \mathbf{0}$

47


Probability
1
0.5
0
0
50
100
Lighting difference (degrees)
50
20
10

48

49



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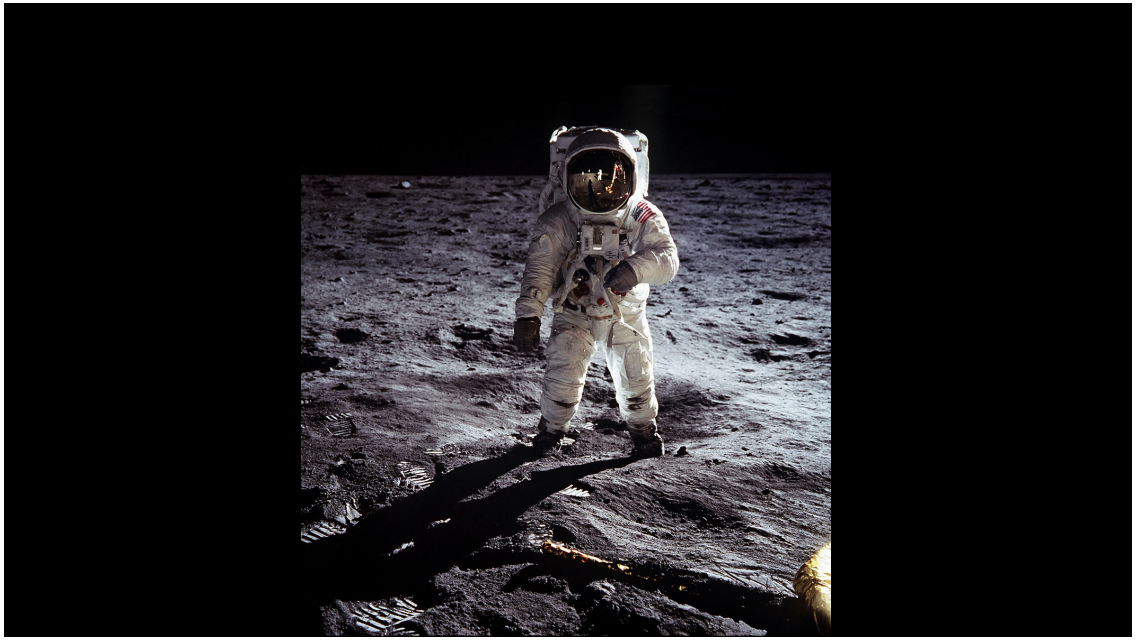

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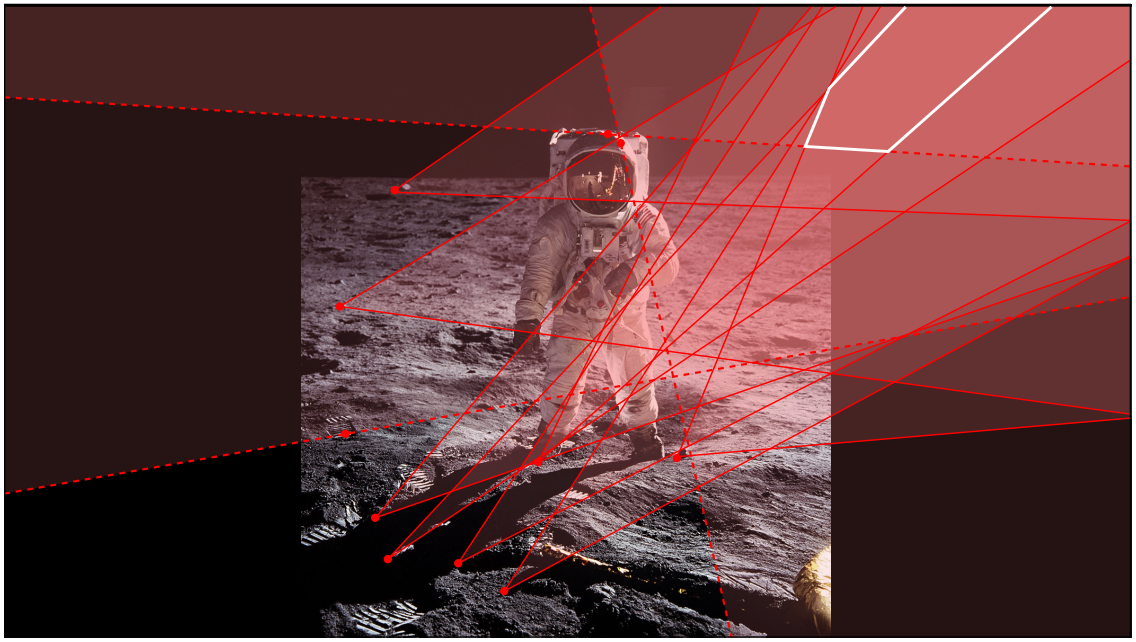

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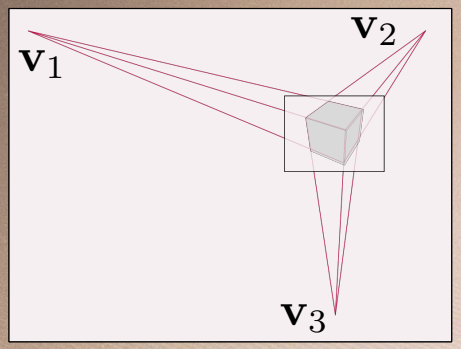
Center of Projection

- COP determined by 3 orthogonal vanishing points



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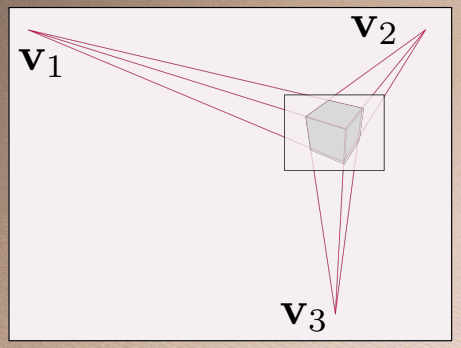
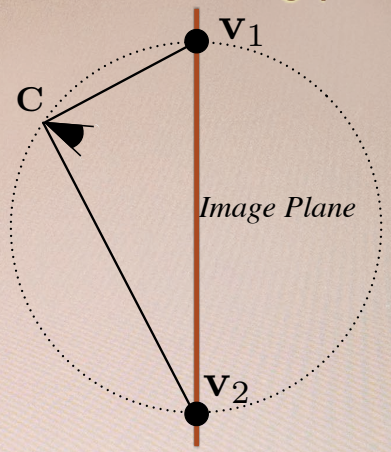
Center of Projection

- COP determined by 3 orthogonal vanishing points





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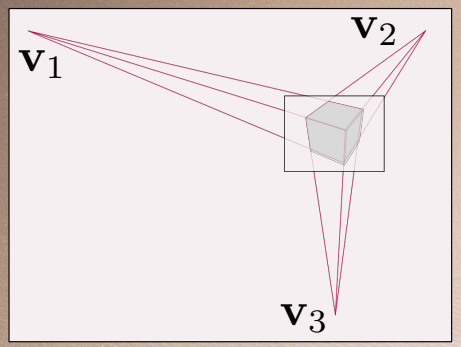
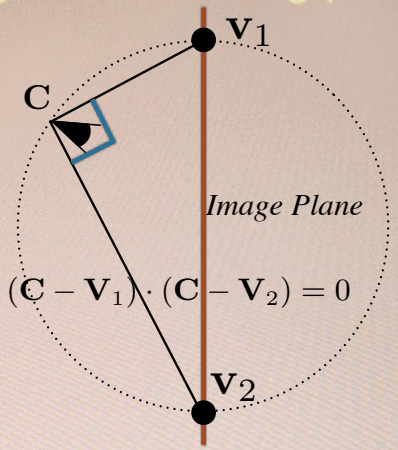
Center of Projection

- COP determined by 3 orthogonal vanishing points





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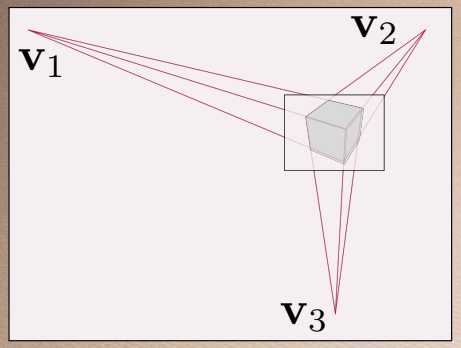
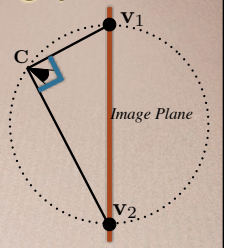
Center of Projection

- COP determined by 3 orthogonal vanishing points



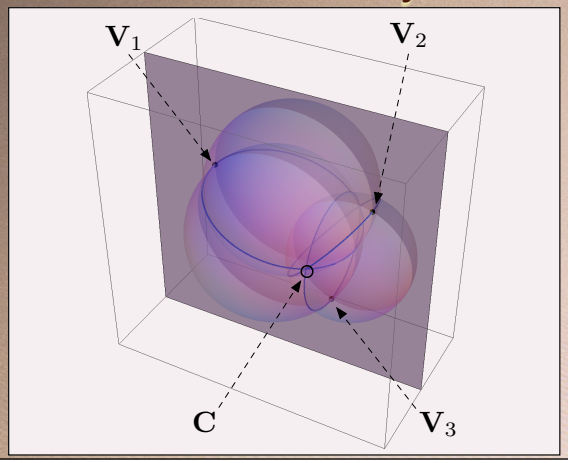


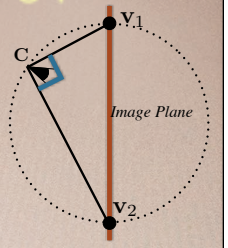
$$(\mathbf{C}-\mathbf{V}_1)\cdot(\mathbf{C}-\mathbf{V}_2)=0$$
$$(\mathbf{C}-\mathbf{V}_2)\cdot(\mathbf{C}-\mathbf{V}_3)=0$$
$$(\mathbf{C}-\mathbf{V}_3)\cdot(\mathbf{C}-\mathbf{V}_1)=0$$

57

Center of Projection

- COP determined by 3 orthogonal vanishing points





$$(\mathbf{C}-\mathbf{V}_1)\cdot(\mathbf{C}-\mathbf{V}_2)=0$$
$$(\mathbf{C}-\mathbf{V}_2)\cdot(\mathbf{C}-\mathbf{V}_3)=0$$
$$(\mathbf{C}-\mathbf{V}_3)\cdot(\mathbf{C}-\mathbf{V}_1)=0$$

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Center of Projection

- COP determined by 3 orthogonal vanishing points
- System of quadratic equations

$$(\mathbf{C} - \mathbf{V}_1) \cdot (\mathbf{C} - \mathbf{V}_2) = 0$$
$$(\mathbf{C} - \mathbf{V}_2) \cdot (\mathbf{C} - \mathbf{V}_3) = 0$$
$$(\mathbf{C} - \mathbf{V}_3) \cdot (\mathbf{C} - \mathbf{V}_1) = 0$$

- Easy to solve by change of variables

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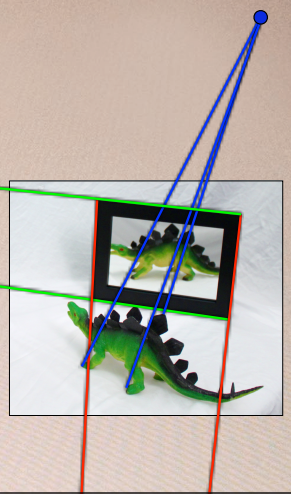
Center of Projection

- Building and other structures
- Reflectors with rectangular frames



- Frames: two orthogonal vanishing points
- Reflected features: third vanishing point
- Compare COP from separate elements in the image

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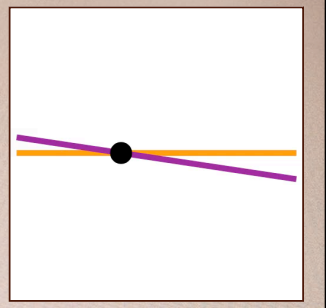
Center of Projection

- Computation is unstable
  - Step 1: intersect [nearly parallel] lines
  - Step 2: intersect spheres



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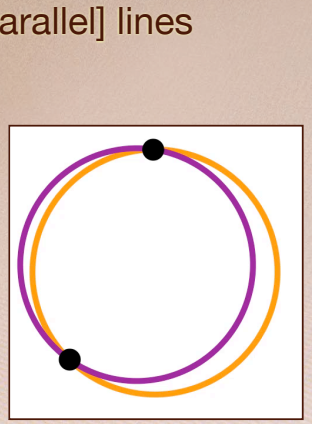
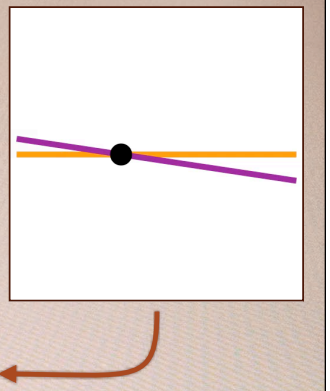
Center of Projection

- Computation is unstable
  - Step 1: intersect [nearly parallel] lines
  - Step 2: intersect spheres
- "Instability squared"





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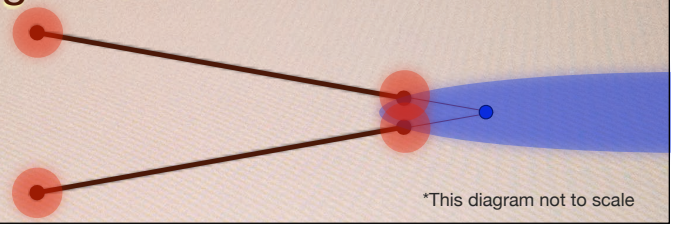
Center of Projection

- Error sources:
  - Image resolution
  - User pointing accuracy
  - Features from different perspectives
- COP calculation magnifies error
  - Structure in instability

Specify regions, not points



*This diagram not to scale

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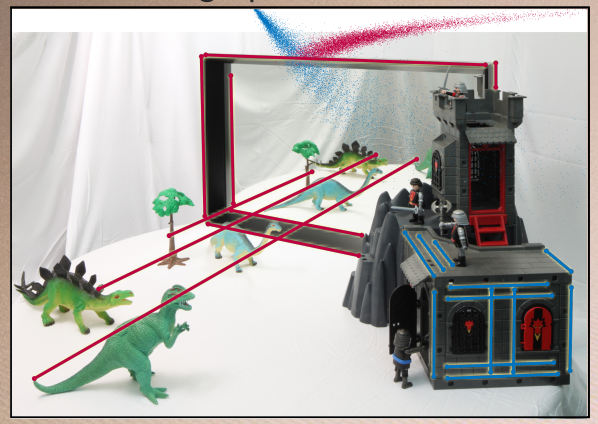
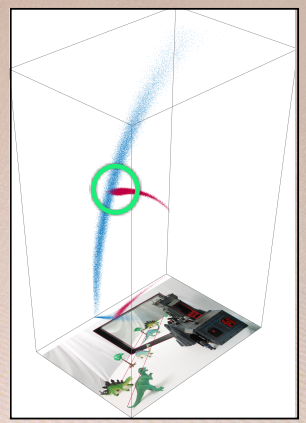
Center of Projection

Real Photograph





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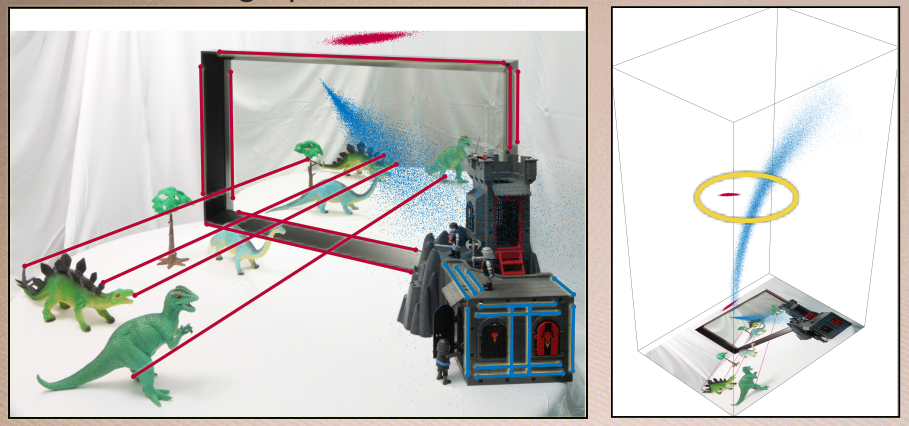
Center of Projection

Altered Photograph



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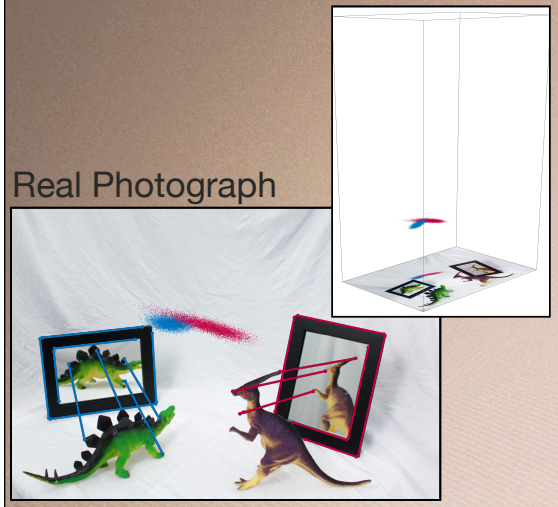
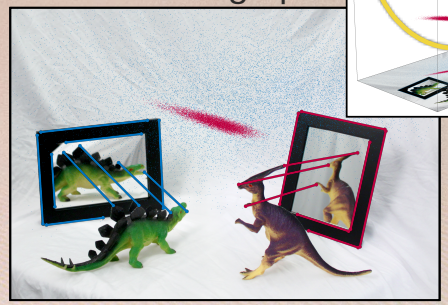
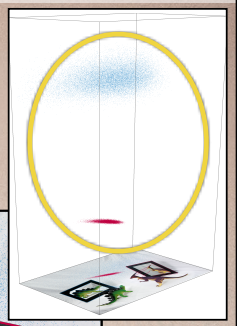
Center of Projection

Real Photograph



Altered Photograph





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CoP from Faces

Work in progress

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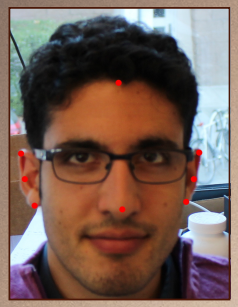
CoP from Faces



Work in progress

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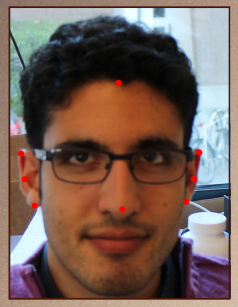
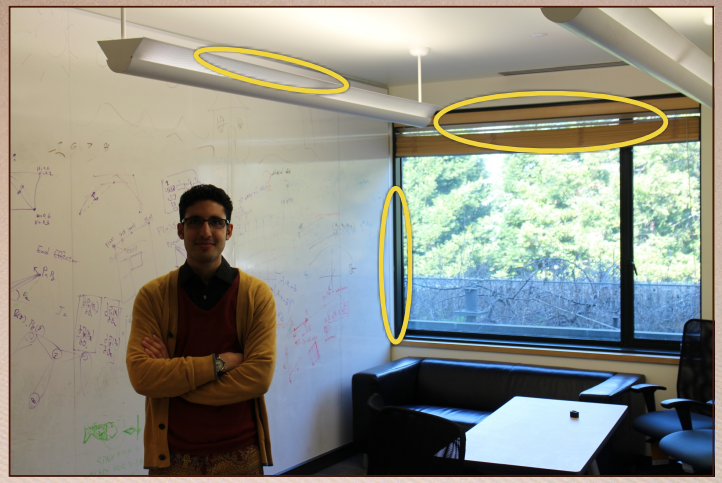
CoP from Faces





Work in progress

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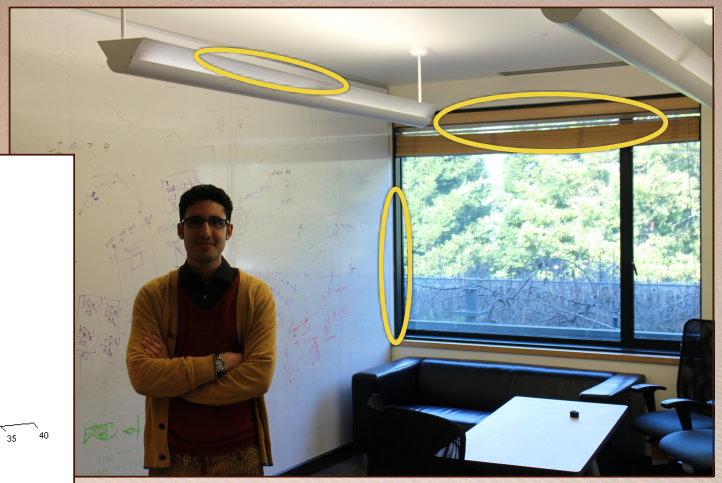
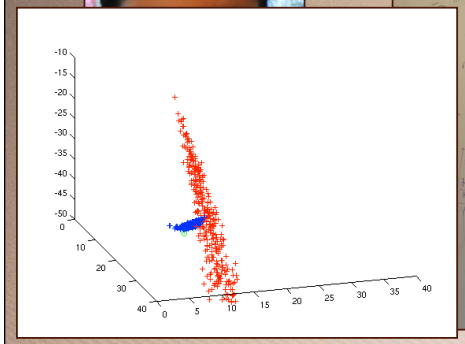
CoP from Faces





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Summary

- Geometric Image Forensics
  - Human annotation
  - Computer analysis
- Part of “analysis toolbox”
  - Not always applicable
  - Together make forgery more difficult
  - Constrain image content

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Big Data Bandwagon

- **Learn to automatically detect images that are *likely* to be forgeries?**
  - **Ignore minor retouching?**
  - **Can we quantify “artificiality” in some way?**

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Thank You

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Relevant Papers

- Eric Kee, James F. O'Brien, and Hany Farid. "Exposing Photo Manipulation with Inconsistent Shadows". ACM Transactions on Graphics, 32(4):28:1–12, September 2013. Presented at SIGGRAPH 2013. http://graphics.berkeley.edu/papers/Kee-EPM-2013-09

- Valentina Conotter, James F. O'Brien, and Hany Farid. "Exposing Digital Forgeries in Ballistic Motion". IEEE Transactions on Information Forensics and Security, 7(1):283 – 296, February 2012. http://graphics.berkeley.edu/papers/Conotter-EDF-2012-02

- James F. O'Brien and Hany Farid. "Exposing Photo Manipulation with Inconsistent Reflections". ACM Transactions on Graphics, 31(1):4:1–11, January 2012. Presented at SIGGRAPH 2012. http://graphics.berkeley.edu/papers/Obrien-EPM-2012-01

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