Accidental pinhole and pinspeck cameras: revealing the scene outside the picture

Maps

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Outline

1. Introduction
2. Methods
3. Applications
4. Summary
5. Discussion

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Introduction

What is it about?

Introduction

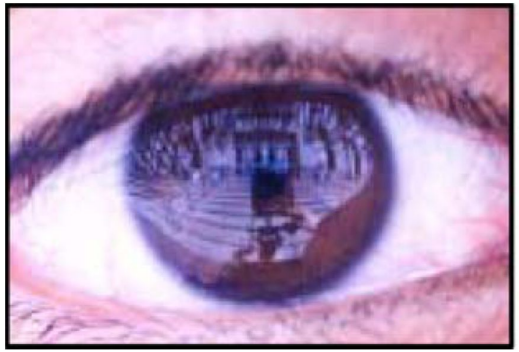
- Images often contain more information than that can be directly visible to the naked eye.

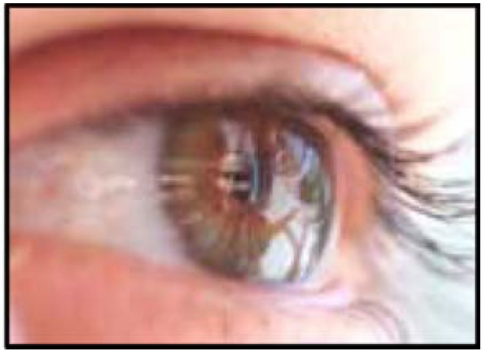
- But what techniques are already out there to extract this?

Introduction - Related Work

Introduction - Related Work

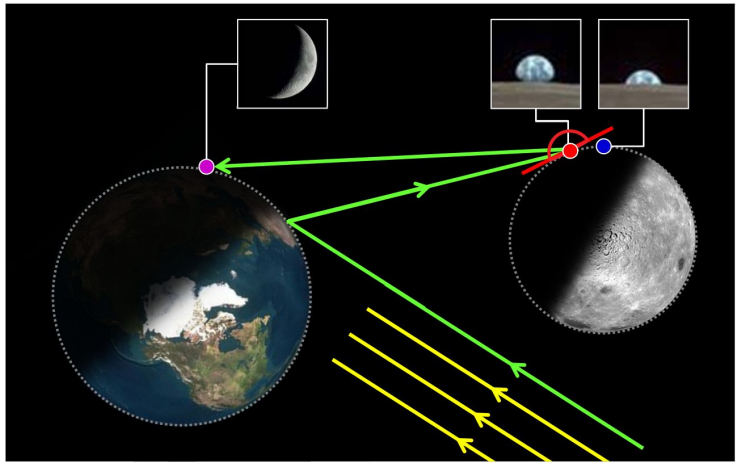
- Eye reflectance can be used to reconstruct the outside world [12]

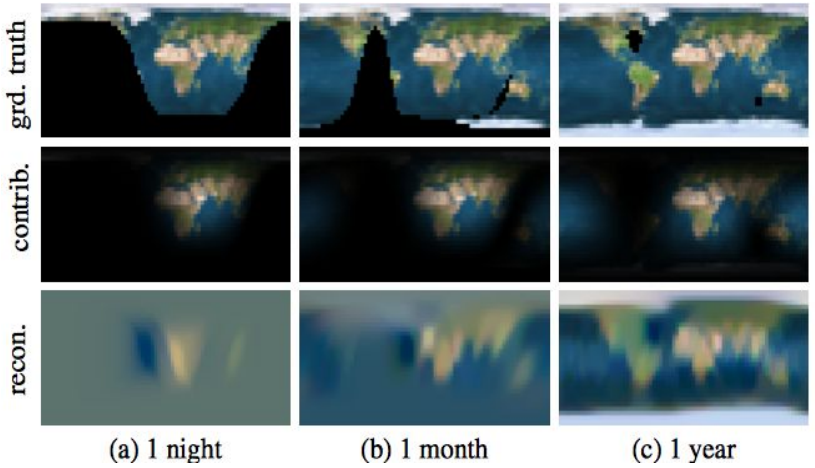




Introduction - Related Work

- Earth can be reconstructed from the moon's reflectance seen from earth [5]





Introduction - More

- Single image depth estimation, separate light sources or obtain a wider image view from single sensor cameras.
  - Depth can be learned from perspective [4]
  - Images can be de-blurred by kernel est. [6]

Introduction - More

- Depth can be learned from perspective detection [4]
- Used here for: 3D Reconstruction

"We describe how 3D affine measurements may be computed from a single perspective view of a scene given only minimal geometric information determined from the image. This minimal information is typically the vanishing line of a reference plane, and a vanishing point for a direction not parallel to the plane."

Introduction - More

- Images can be deblurred by kernel estimation [6]
- Used here for: Window Shape Estimation

Algorithm 1 : Overall Algorithm

Require: Observed blurry image g, Maximum kernel size h.

Apply derivative filters to g, creating a high-freq. image y.

1. Blind estimation of blur matrix K (Section 3.1) from y.
   Loop over coarse-to-fine levels:
   Alternate:
   - Update sharp high-frequency image x (Section 3.1.1) using l_1/l_2 regularization.
   - Update blurring matrix K (Section 3.1.2).

   Interpolate solution to finer level as initialization.

2.Image recovery using non-blind algorithm of [12] (Section 3.2).
   - Deblur g using K to give sharp image u.

return Sharp image u.

Introduction - Ending

- These techniques are able to extract more information about the world from often single images
- What sets this paper apart?
  - Focuses on extracting information from outside the image frame.
  - Uses diffuse surrounding surfaces.

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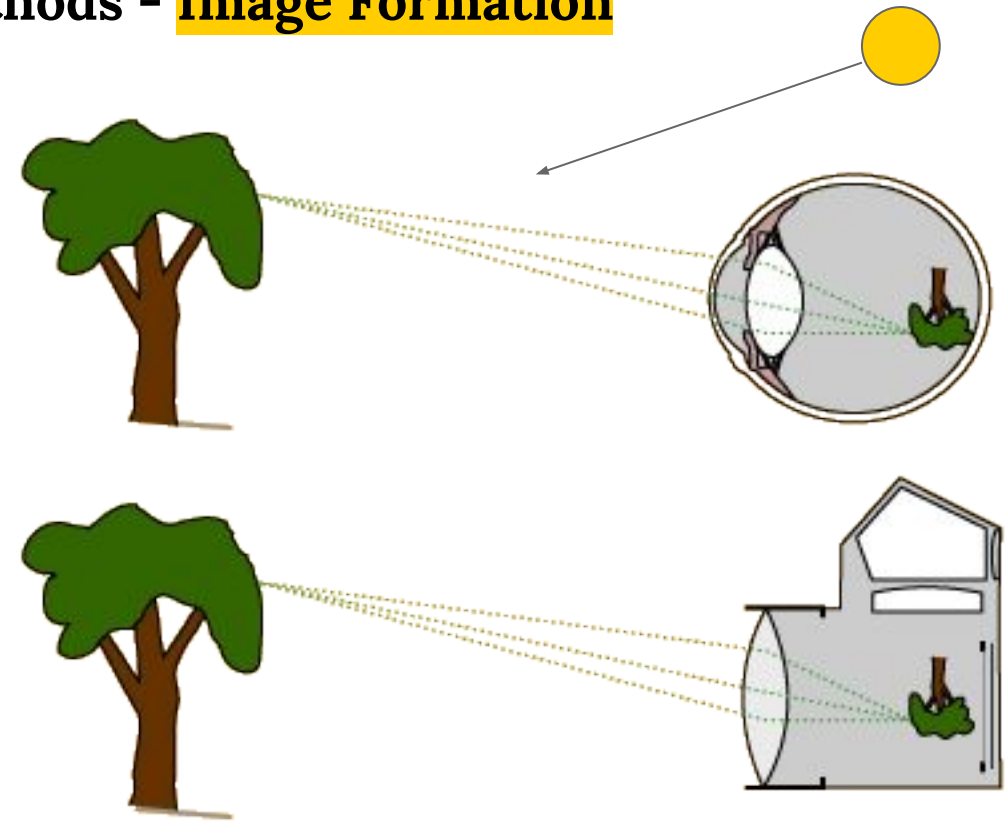
Methods

What methods did they use in their applications?

Methods - Introduction

- Paper uses a variety of techniques that share a common denominator: Pinspeck Camera
  - Outside View
  - Extracting Light Sources
  - Window Shape
  - 3D Reconstruction
- These techniques are explained in Applications, but let's first overview what a Pinspeck Camera is and what its limitations are.

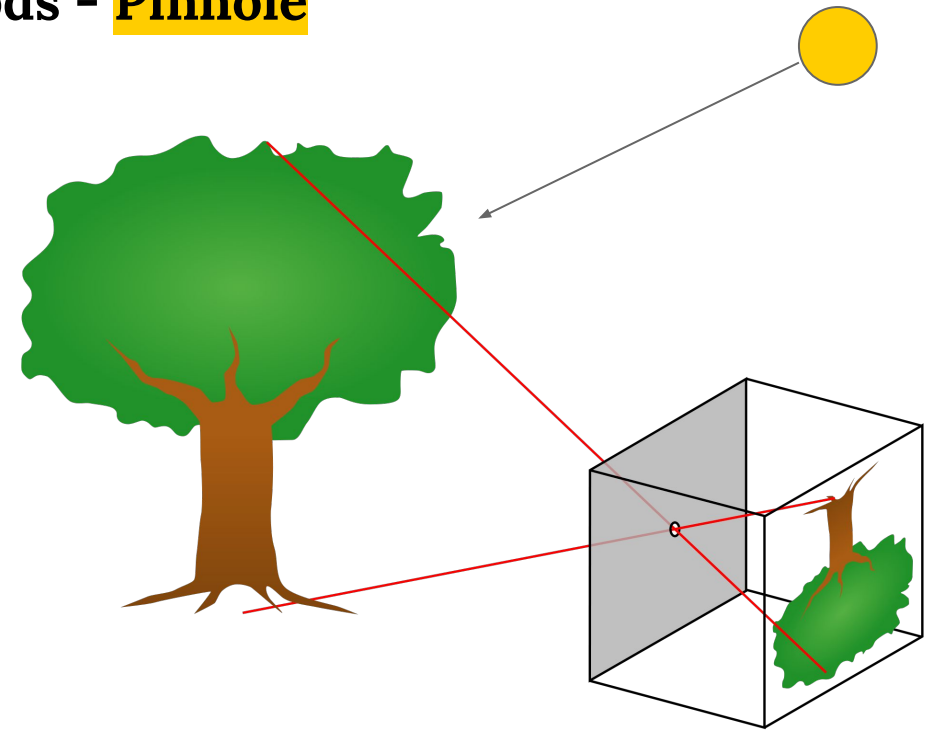
Methods - Image Formation



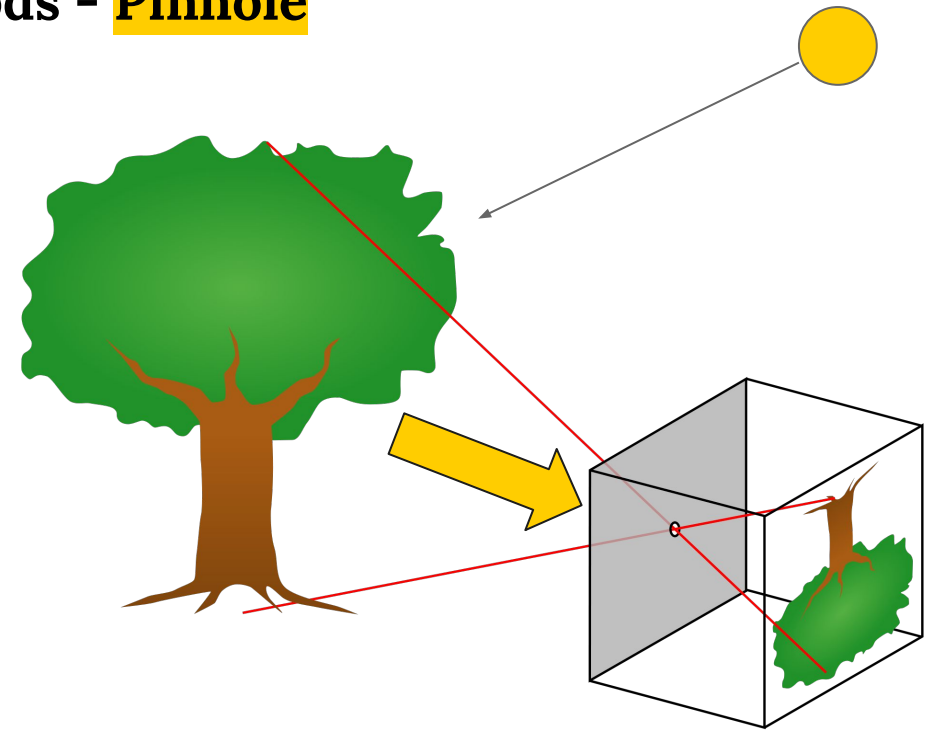
Methods - Image Formation

- Image extraction devices are designed (e.g. cameras and in living beings).
- Not only there, but they are also formed accidentally in nature.
  - From the title: *Accidental* pinhole and pinspeck cameras: revealing ...

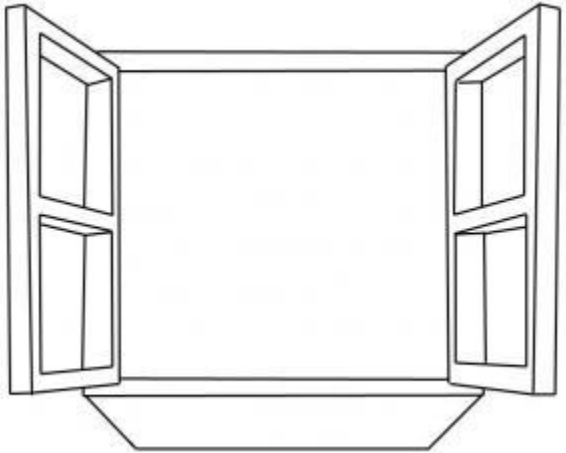
Methods - Pinhole



Methods - Pinhole

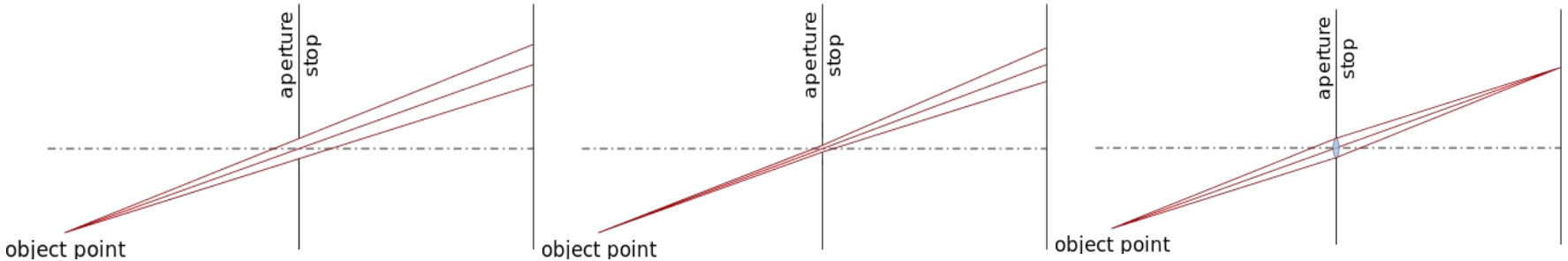


Methods - Pinhole



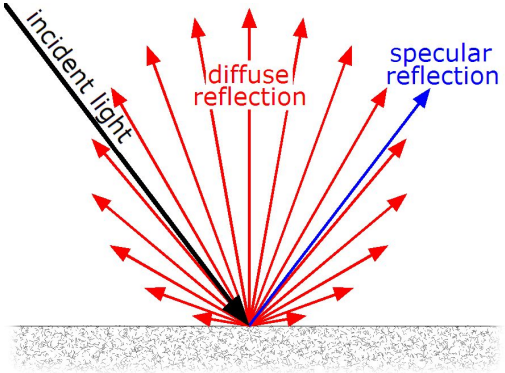
Methods - Pinhole

- However, without a lense that focuses light from one source point to one point in the ‘image’ or a sufficiently small aperture the appearance of the resulting image is blurry.



Methods - Pinhole

- Loosely related is the Signal to Noise Ratio (SNR) which compares the level of desired signal to the level of background noise. Becomes important later.
- E.g. lambertian reflectance of walls and objects



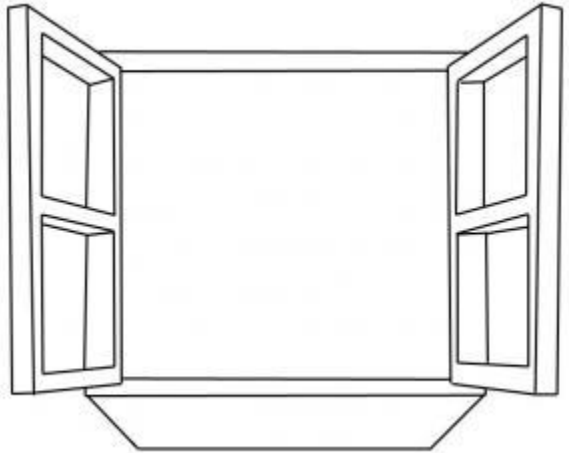
Methods - Pinhole

- Extreme example (with extended exposure)

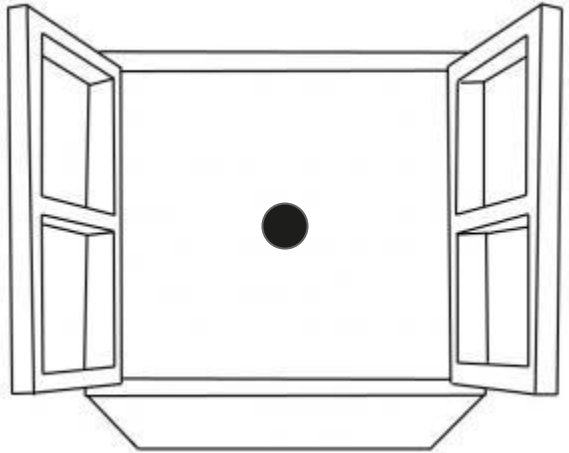
Methods - Pinspeck

- Pinspeck Cameras occur more frequently than Pinhole Cameras as they pose fewer constraints on the environment.
- They are also called 'Inverse Pinhole' Cameras as will be explained shortly.

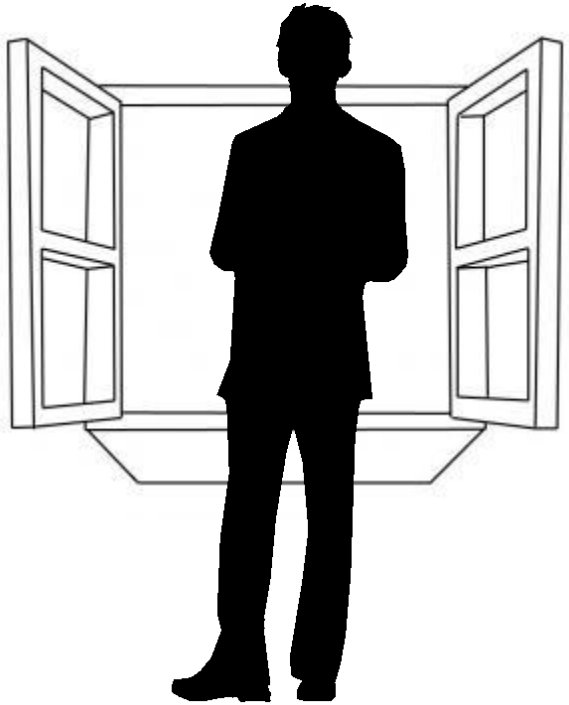
Methods - Pinspeck..



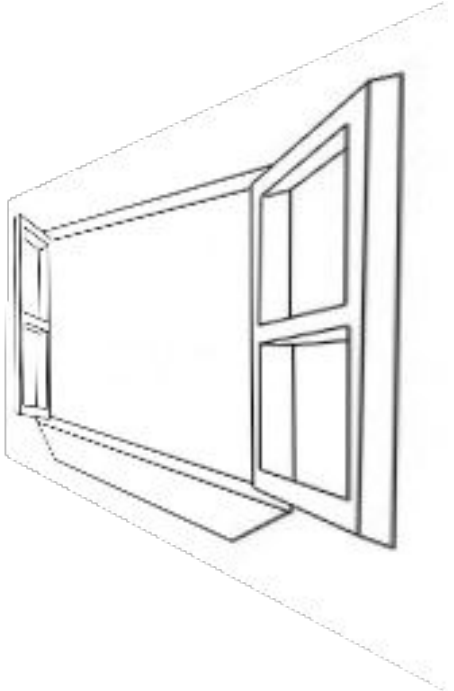
Methods - Pinspeck



Methods - Pinspeck



Methods - Pinspeck

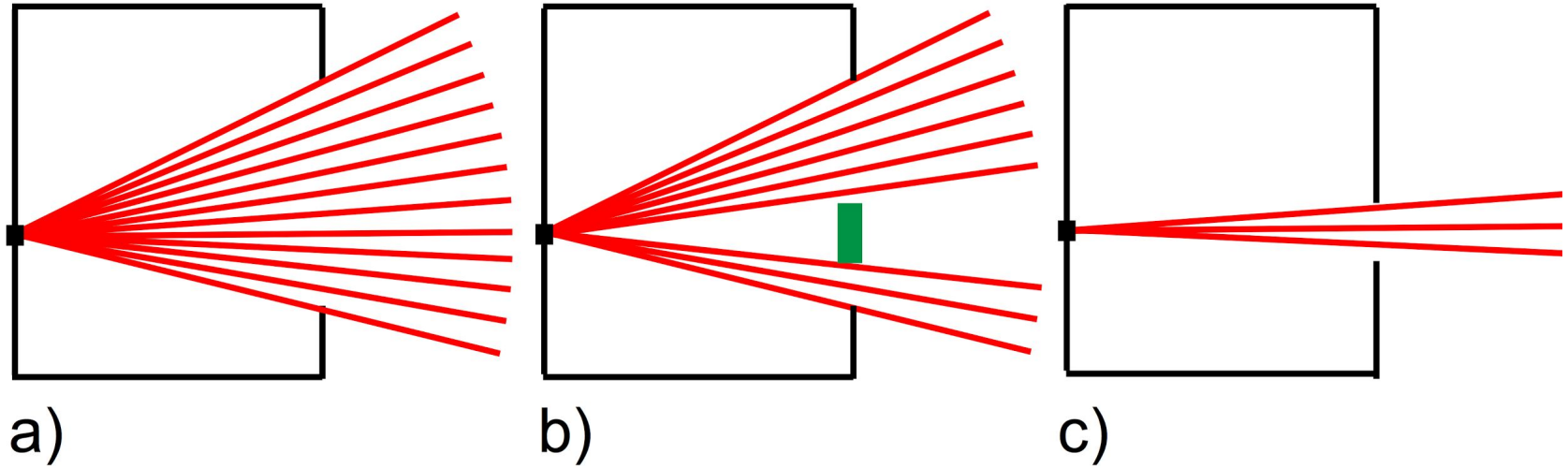


Methods - Pinspeck

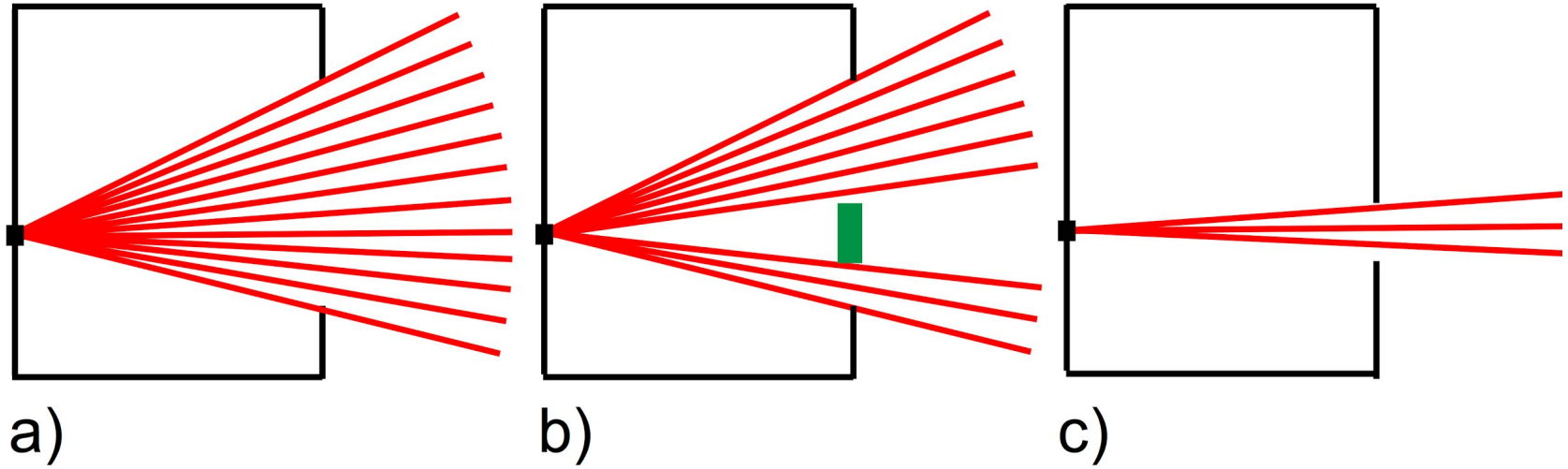
Methods - Pinspeck

- Often the difference in wall lighting goes unnoticed, but they are not the same.
- Idea: Use this difference to obtain an inverse pinhole.

Methods - Pinspeck

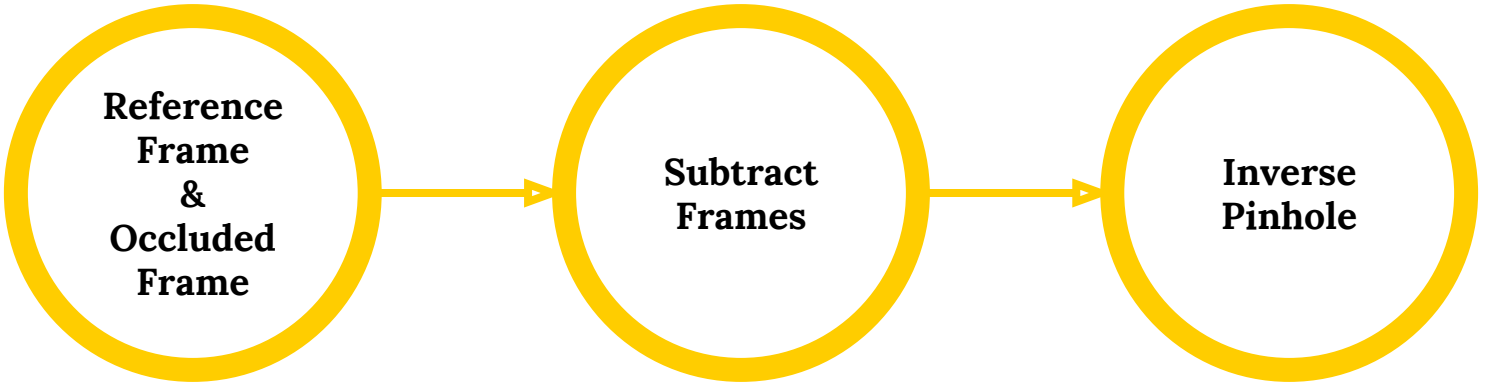


Methods - Pinspeck



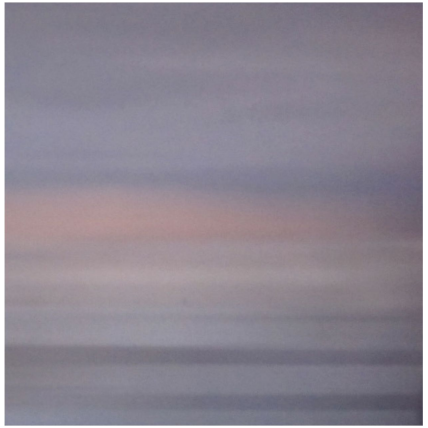
$$I_{window}(x) - I_{occludewindow}(x) = T_{hole}(x) * S(x)$$

Methods - Pinspeck



Methods - Camera Alignment

- Correcting the surface-camera orientation with homography



Methods - Reference Image

- Reference frame is required, two methods are used
  - Frame with highest intensity (single frame)
    - Assumption: least occlusion
  - Average over multiple frames and use selection that subjectively gives the best results.

Methods - Limitations

- Requires a reference image
- Signal-To-Noise (SNR) ratio, assuming Poisson noise:

$$A = \int T(x)dx \qquad SNR = \frac{A_{occluder}}{\sqrt{A_{window}}}$$

- Trade-off between sharpness and amount of noise

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Applications

How can it be used?

Applications - Revisiting

- Outside View
- Extracting Light Sources
- Window Shape
- 3D Reconstruction

Applications - Outside View

- Extracting accidental image of outside view from changing light on a room wall
- Example: Video of a room wall
  - A person passes in front of the window causing changes in illumination.
  - Reference image - average over first 50 frames

Applications - Outside View

Actual view

Applications - Outside View

Applications - Outside View

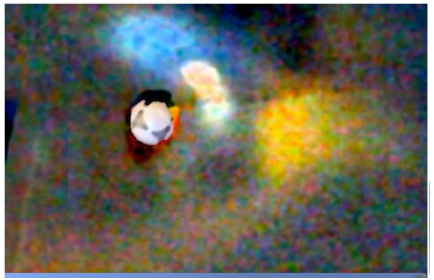
Actual view

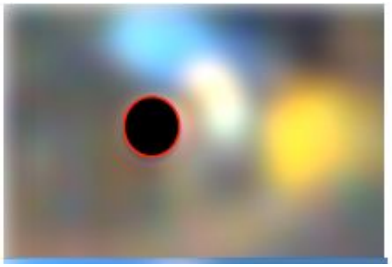
Body occlusion

Hand occlusion

Applications - Outside View

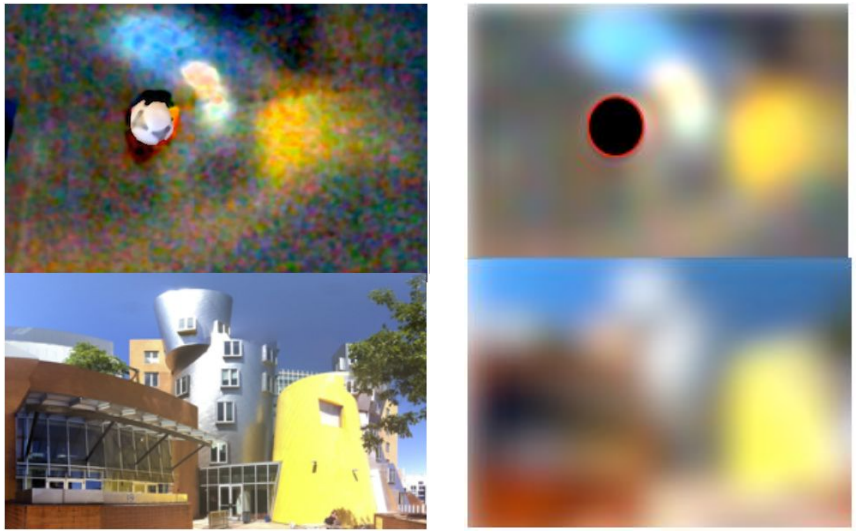
- The same technique can be used for outside environment.





Applications - Outside View

- The same technique can be used for outside environment.

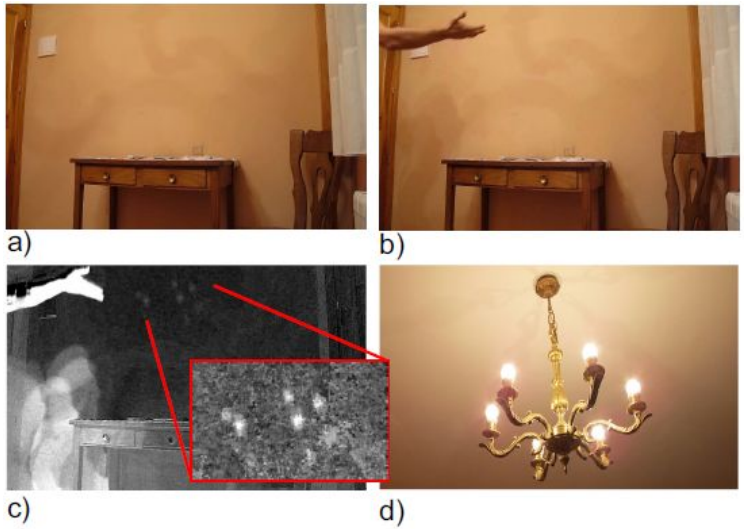


Applications - Light Sources

- Extracting accidental image of the light source(s) in a room
- Example: Video of a room with a light source inside it
  - A person throws a ball between the light source and the visible wall

Applications - Light Sources

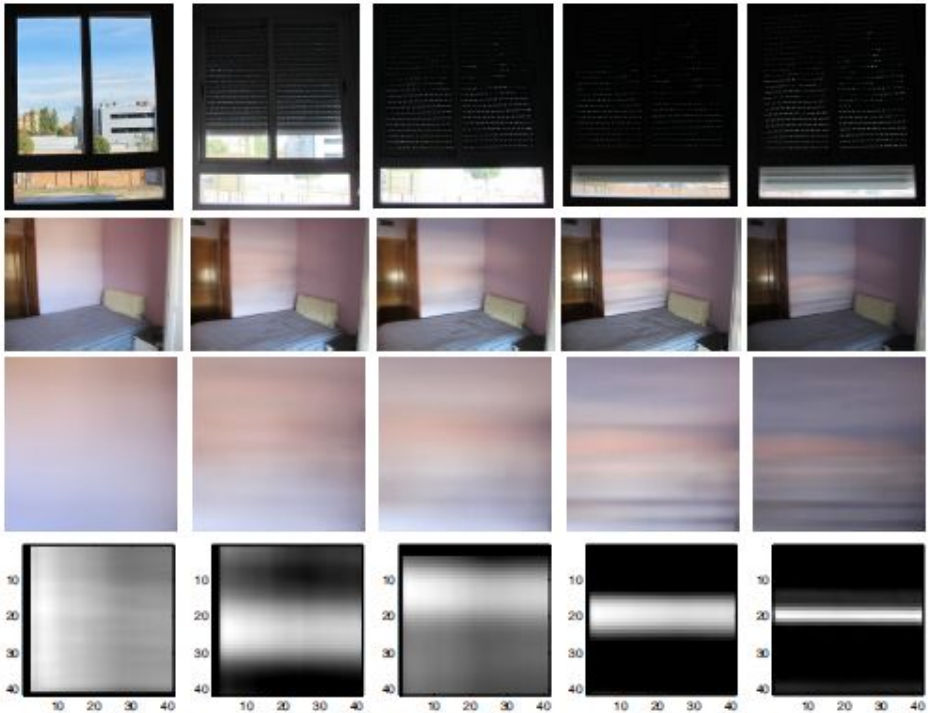
- SNR is high, so only the light source image can be extracted



Applications - Window Shape

- Determining the shape of a window from the produced illumination
- Different from outside world view
  - Single image
  - Deblurring technique is applied

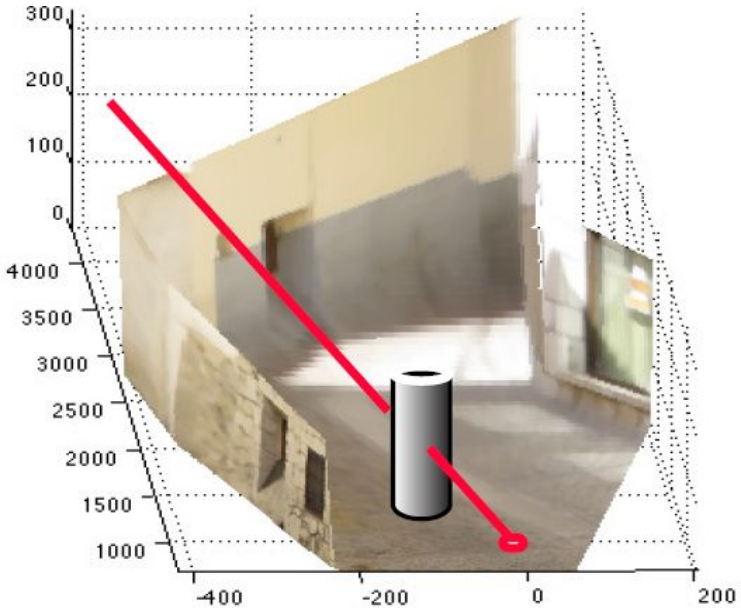
Applications - Window Shape



Applications - 3D Reconst.

- Infer where light comes from
- 3D reconstruction of the scene outside the picture
- Example: Video of a man walking on a street
  - Recovering metric 3D from object annotations with LabelMe 3D (uses single view metrology [13])
  - Fill in missing parts with accidental image information

Applications - 3D Reconst.



6 Summary

Conclusion on what is new?

Summary

- Using pinspeck camera technique can reveal accidental images within a scene.
- These images give information about the lighting conditions, the view outside the visible scene and the shape of the window.

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Discussion

What could be improved upon?

Discussion

- Explanations sometimes lack formality (e.g. with the explanation of SNR)
- Missing information (e.g. 3D reconstruction not well explained, details of experimental setup missing)

Thanks!

Any questions?

References

[0] Accidental pinhole and pinspeck cameras: Revealing the scene outside the picture.

[4] Single View Metrology.

[5] Diffuse Reflectance Imaging with Astronomical Applications.

[6] Blind Deconvolution Using a Normal Sparsity Measure.

[12] Exposing Photo Manipulations with Inconsistent Reflections.