

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



Maps

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## Who we are



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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?

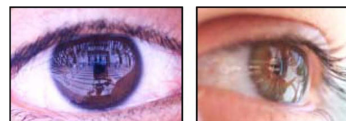


### Introduction - Related Work



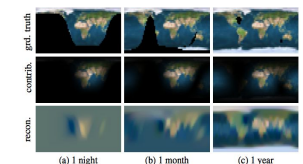
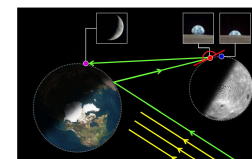
### Introduction - Related Work

- 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  $y$ , Maximum kernel size  $h$ .  
Apply derivative filters to  $y$ , 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  $y$  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.

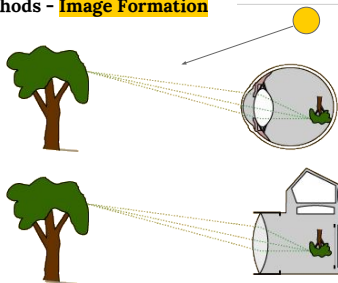
## 1 Methods

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.

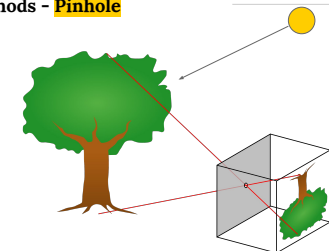
## Methods - Image Formation



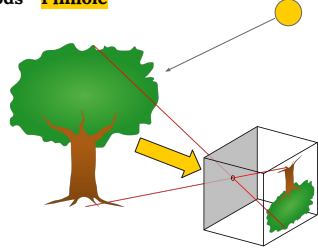
## Methods - Image Formation

- 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 ...

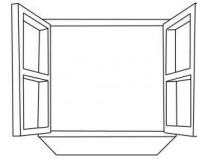
## Methods - Pinhole



## Methods - Pinhole

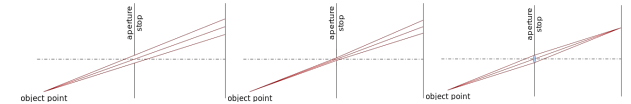


## Methods - Pinhole



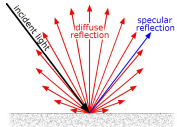
## Methods - Pinhole

- 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

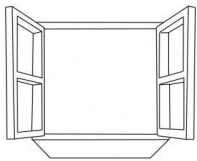
- Extreme example (with extended exposure)



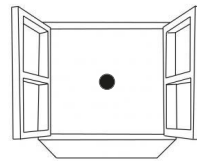
## Methods - Pinspeck

- **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.

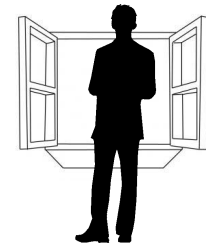
## Methods - Pinspeck..



## Methods - Pinspeck



## Methods - Pinspeck



### Methods - Pinspeck



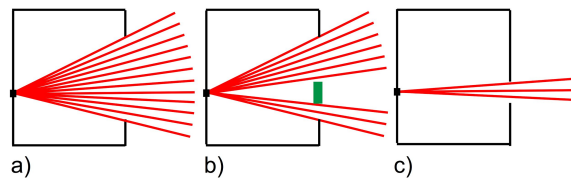
### Methods - Pinspeck



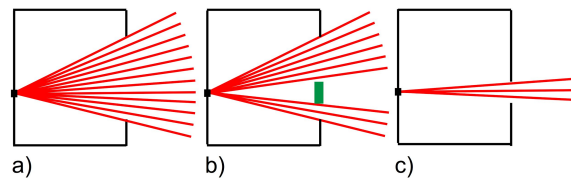
### Methods - Pinspeck

- 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

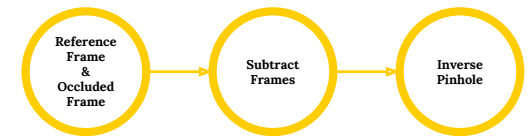


### Methods - Pinspeck



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

### 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:

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

- Trade-off between sharpness and amount of noise

## 5 Applications

How can it be used?

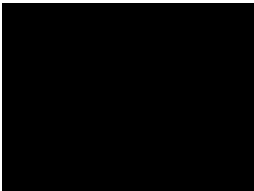
### Applications - Revisiting

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

### Applications - Outside View

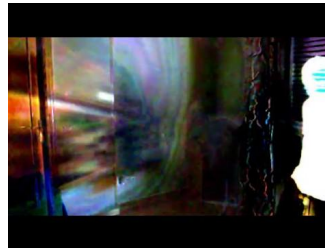
- Extracting accidental image of outside view from changing light on a room wall
- Example: Video of a room wall
  - A person passes in front of the window causing changes in illumination.
  - Reference image - average over first 50 frames

### Applications - Outside View

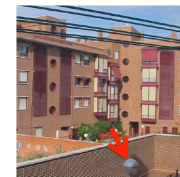


Actual view

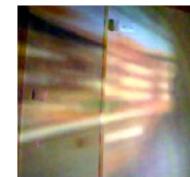
### Applications - Outside View



### Applications - Outside View



Actual view



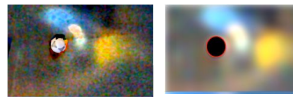
Body occlusion



Hand occlusion

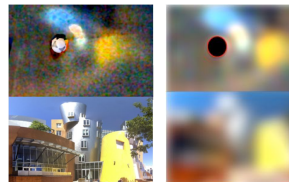
### Applications - Outside View

- The same technique can be used for outside environment.



### Applications - Outside View

- The same technique can be used for outside environment.

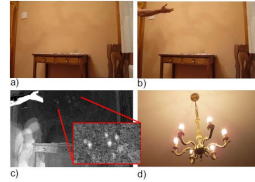


### Applications - Light Sources

- 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

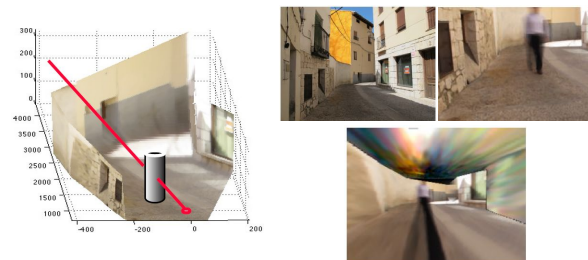
## Applications - Window Shape



## 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 pinspeak 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.

## 7 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)



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# Thanks!

Any **questions?**



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## 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.