



Enhanced Visual Realism by Incorporating Camera Image Effects

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Overview



• **Introduction**

- Simulation of Image Noise
- Antialiasing
- Simulation of Motion Blur
- Results
- Conclusions

Video See-Through AR

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Which one is real?

- Usually **standard real-time graphics** (e.g., OpenGL)
- Rendering **artifacts** like aliasing
- Inconsistent **illumination**

⇒ Solution: **Adapt** the **visual realism**
("photometric registration")

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Related Work

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- Rendering Synthetic Objects Into Real Scenes [Debevec 1998]
- Image-based photometric reconstruction [Gibson et al. 2001]
- Analysis of environment illumination e.g., [Agusanto et al. 2003]
- Opposite approach: Apply artistic video filter e.g., [Fischer et al. 2005]
- Estimation of defocussing and motion blur [Okumura et al. 2006 → *later in this session!*]



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Objective of this Paper

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Create an **equalized** level of **visual realism** by **simulating effects** found in typical **camera images**.

1) Photographic imperfections

- Camera image noise
- Motion blur

2) Antialiasing

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Overview

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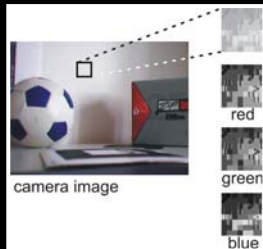
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Camera Image Noise

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Example of image noise

- **Noise** contained in data delivered by digital **image sensor** (CCD / CMOS)
- **Noise characteristics** depend on type of image sensor
- Noise **varies** in each frame (animated)

Idea:

1. **Calibrate** noise characteristics of a given digital image sensor
2. **Simulate** image noise **according to characteristics** in AR system

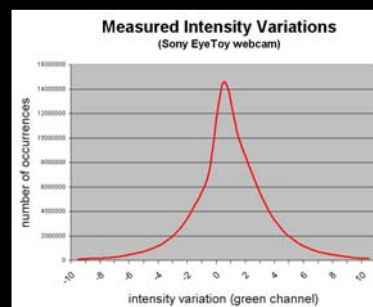
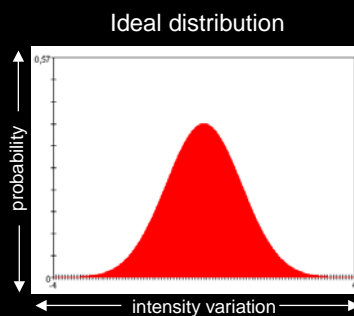
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Image Noise Model

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- Observation: image noise is approximately **normally distributed**



- Normal distribution described by two parameters:
 - **standard deviation** σ
 - **mean** μ (should be zero!)

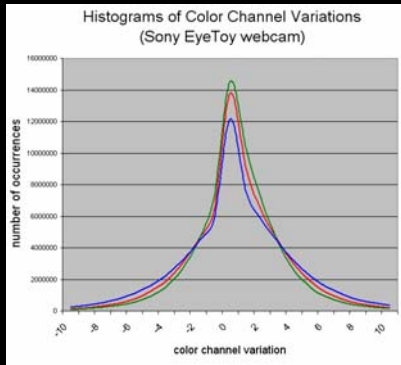
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Image Noise Model - Refinements

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a) Process **color channels** separately



Determine (μ_i, σ_i) individually for color channels (R,G,B)

b) Take **pixel intensity** into account

- Some types of noise depend on **overall intensity** (e.g., shot noise)
- Split intensity range $[0..255]$ into **N bins**
- Compute separate normal distributions **for each bin**
- In total, parameters for **3-N distributions** are determined

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Camera Noise Calibration

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Record (one or several)
static scenes



frames f_{ij}

(i-th scene, j-th frame)

Compute
average
Image a_i

- Compute **channel variations**
$$v_{ij}(x,y) = f_{ij}(x,y) - a_i(x,y)$$
- Compute **histograms** of the v_{ij}
 - for each color channel
 - split into N intensity bins
- Estimate normal distribution **parameters (μ_i, σ_i)** for each bin
 - using **maximum likelihood estimation**

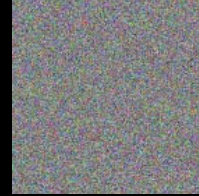
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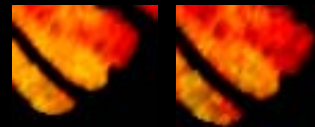
Simulated Noise Overlay

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- **Random noise textures**
 - **Non-uniform** random number generator is used
 - Random offsets in $[-128..+127]$ stored in 8-bit texture
- **Noise offsets added to pixel colors**
 - Shader program selects virtual object pixels
- **Animated noise**
 - Random texture **translation**
 - Random texture **rotation**



RGB noise texture with parameters (μ_i, σ_i) for one intensity bin



original

with simulated noise

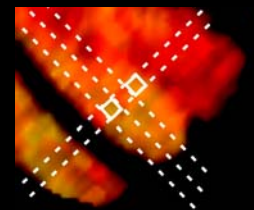
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Simulated Noise Overlay - Refinements

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1. Observation: Color variations in camera image are **patches larger than a pixel**
⇒ Introduce noise **magnification factor**
2. **Scale noise offsets** by definable parameter to **enhance effect**
3. Observation: Real noise **changes rather slowly**
⇒ Introduce **animation delay** for noise texture



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- **Antialiasing**
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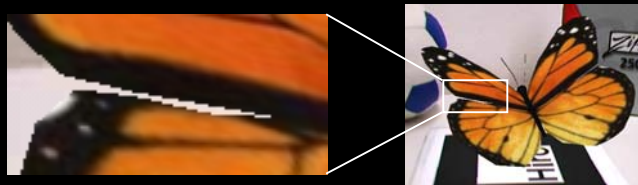
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Aliasing in AR

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Problem: **Aliasing** at the **edges** of virtual objects



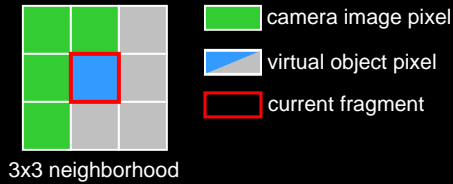
- Noise rendering pipeline has all relevant data
 - location of **virtual object pixels**
 - **camera** and **virtual images** available as **textures**
- **Antialiasing** a simple extension of noise renderer

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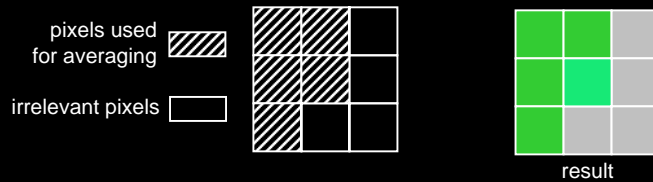
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Antialiasing

- Regard 3x3 neighborhood of virtual object pixels



- Weighted average of current fragment and camera pixels



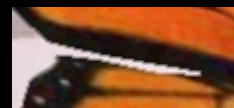
Antialiasing Process

1. Stop if current fragment is no virtual object pixel
2. $n :=$ number of camera pixels in neighborhood
3. Stop if $n = 0$
4. $\mathbf{result} := \frac{1}{(n+1)} \left(\mathit{currentFragment} + \sum_{i=1}^n \mathit{cameraPixel}_i \right)$

- Refinement: Introduce **factor** to determine **impact** of blending effect



without antialiasing



with antialiasing

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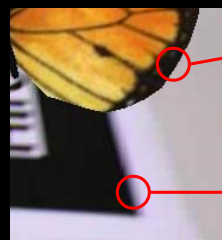
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Motion Blur

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Problem: Movement causes **motion blur** only in camera image



virtual object:
no blur

camera image:
visible motion blur

Idea:

- **Estimate motion blur** based on camera pose
- Render **blurred version** of virtual objects

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Motion Blur Estimation

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- **Project object center** into 2D according to **camera pose**



frame t



frame $t+1$

Blur vector represents
direction and size of blurring

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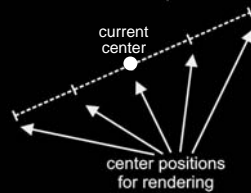
Motion Blur Renderer

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Blur vector:



Generated center positions:



- **Vector length threshold** enables motion blur rendering
- Center blur vector at **current object center**
- Render **multiple copies** of virtual object
- Blend **semi-transparent** copies



Virtual butterfly rendered with motion blur

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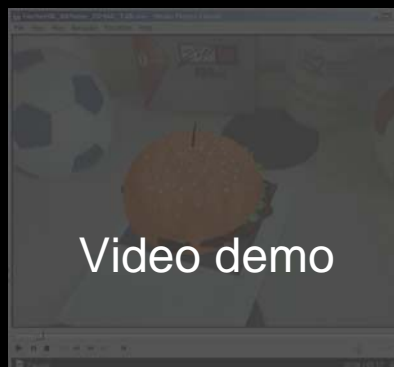
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Results - Video

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- Implementation uses **custom shaders** on the GPU



- Noise/antialiasing **> 29 fps** (webcam 640x480 @ 30 Hz)
- Motion blur depends on blur size, typically **> 20 fps**

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Noise Rendering:

- New **noise calibration** step
- Real-time noise **simulation** on the GPU
 - Consider **simplified model** (e.g., intensity bins)
 - Future work: Measure **geometric/temporal noise pattern**
 - Future work: **User study** on effects of noise simulation

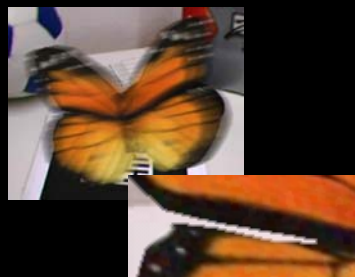
Antialiasing:

- Method for **reducing aliasing** between real and virtual images
- Future work: Apply **advanced sampling** methods

Motion Blur:

- Motion **blur estimation** and **rendering** method
- Only works if tracking data is available
 - ⇒ Possible solution with **image-based** approach
[see last talk in this session!]

**Thank you for
your attention!**



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More information:

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