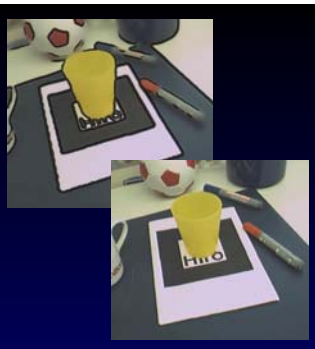
Measuring the Discernability of Virtual Objects in Conventional and Stylized AR



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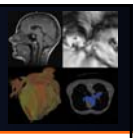
WS GRIS Overview



- **Introduction**
- Cartoon-like Stylization for AR
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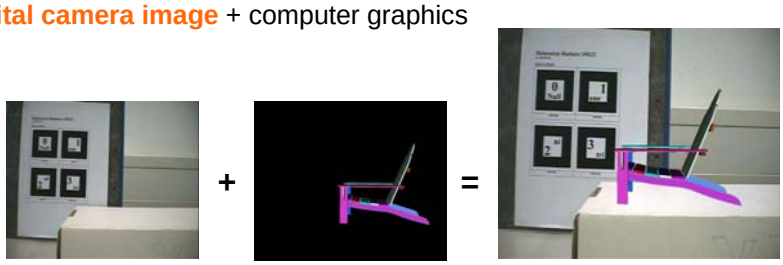
What is Augmented Reality?

Definition [Azuma 1997]

- **Fusion** of real view and computer graphics
- Real-time, **interactive** system
- Correct **three-dimensional alignment** (*tracking!*)

Video see-through AR

- **Digital camera image** + computer graphics



Rendering for Augmented Reality

Which one is real?

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

⇒ ***Important*** *and* ***difficult*** *challenge*

Previous Work: Rendering in AR

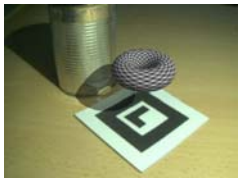
Analysis of environment illumination

[Agusanto et al. 2003]

Occlusion handling

[Fischer et al. 2004]

Addition of shadows



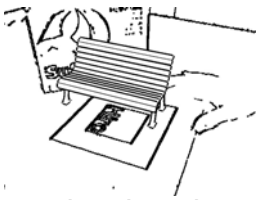
[Haller et al. 2003]

Stylized rendering in AR

[Haller 2004]

Stylized Augmented Reality

- **Novel approach** to generating AR video streams
- Apply **stylization methods** to AR image
- Use **same type** of stylization for
  - camera image and
  - virtual objects

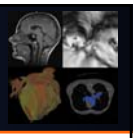


Sketch style
[Fischer et al., IEEE VR 2005]

Pointillism style
[Fischer et al., VRST 2005]

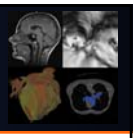
Cartoon-like style
[Fischer et al., ISMAR 2005]

Stylized AR: Requirements



1. **Equivalent stylization** for real and virtual objects
2. (**More than**) **Real-time** performance
3. Fully **automatic** stylization
4. Handle **different types of input data**:
   - 2D video stream (frame coherence, noise)
   - 3D virtual objects

Overview



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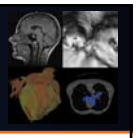
Cartoon-like Stylization for AR

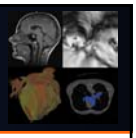


- Psychophysical study is based on **cartoon-like stylization**
- Fast, high-quality approach for the **stylization of AR images**
- Designed as a **post-processing** filter

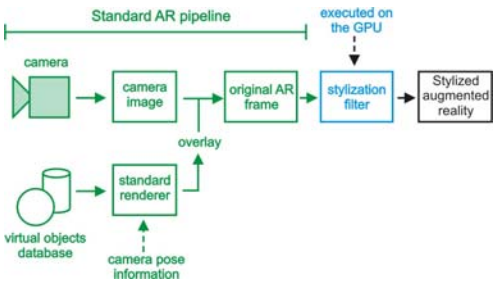
- Application **after** combining real and virtual images
- Execution **on the GPU**
- Implemented in the **OpenGL Shading Language**

Image generated by the cartoon-like stylization algorithm

Stylization Filter Pipeline



Data **stored in graphics card memory** is processed

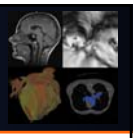


Elements of cartoon style:
- Uniformly **colored patches**
- Black **silhouette lines**

[from disyneysites.com]

Two filtering steps
- **Color simplification**
- **Edge detection**

Color Simplification



- New non-linear filter inspired by bilateral filtering
- No distance weight
- Only takes color difference in YUV space into account

Summation over neighborhood

Current pixel

Normalization

Pixel weight

$$\mathbf{h}(\mathbf{x}) = k^{-1}(\mathbf{x}) \sum_{\xi \in \Omega_\mathbf{x}} \mathbf{f}(\xi)\, s(\mathbf{f}_{UV}(\xi), \mathbf{f}_{UV}(\mathbf{x}))$$

$$s(\mathbf{f}_{UV}(\xi), \mathbf{f}_{UV}(\mathbf{x})) = e^{-\frac{1}{2}\left(\frac{|\mathbf{f}_{UV}(\xi) - \mathbf{f}_{UV}(\mathbf{x})|}{\sigma_p}\right)^2}$$

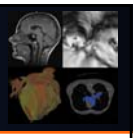
Pixel weight

Difference of U and V components

Original image

Simplified color image

Edge Detection



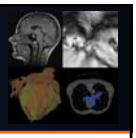
- Special edge detection method based on the Sobel filter
- **Adaptive weighting** of color (U,V) and intensity (Y) gradients
- Takes **original and simplified** color images into account

Original image

Edges in original image

Edges in simplified image

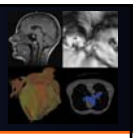
Implementation

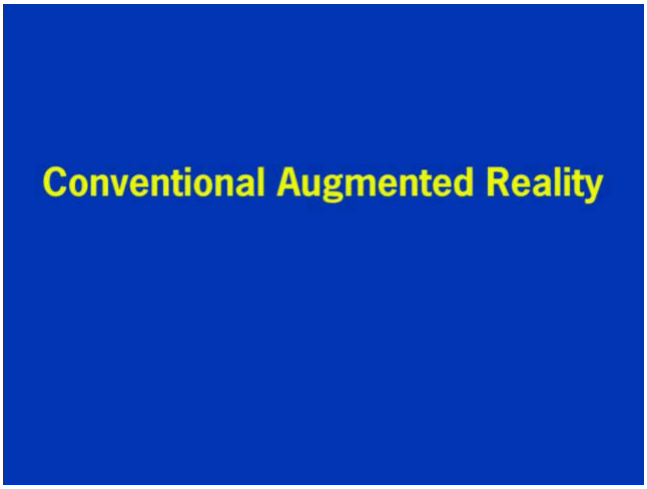


- Color simplification and edge detection are performed **on the GPU**
- Input and intermediate data stored as **textures**
- Optimized **texel address computation** scheme
- Overall frame rate **> 25 fps** for a typical setup

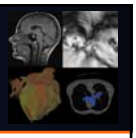
- J. Fischer et al., *Reality Tooning: Fast Non-Photorealism for Augmented Video Streams (poster)*, IEEE and ACM ISMAR, pages 186-187, 2005
- J. Fischer et al.: *Real-time Cartoon-like Stylization of AR Video Streams on the GPU*, Technical Report WSI-2005-18, WSI, University of Tübingen, 2005

Cartoon-like Stylization Video





Overview



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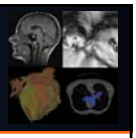
Experimental Methodology



- **Psychophysical study** on the discernability of virtual objects
- Study designed as an **offline task**
  - **Recorded images** and video clips were shown
  - **No interactive** augmented reality setup
- **18 participants** paid at standard rates
  (not related to lab, no previous experience with AR)
- 9 participants were shown **static images**
- 9 participants were shown **short video clips**
- Images / videos were displayed on conventional **PC monitor**

Objects used in the Study

- **15 real** objects, **15 virtual** objects
- **Standardized, simple setting** with object placed over marker

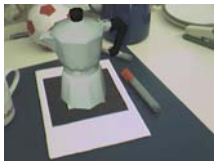

Real object


Virtual object

- **Conventional** and **stylized** images recorded for each object


Real, conventional AR


Real, stylized AR


Virtual, conventional AR


Virtual, stylized AR

- **Total of 60 images / video clips** shown to each participant

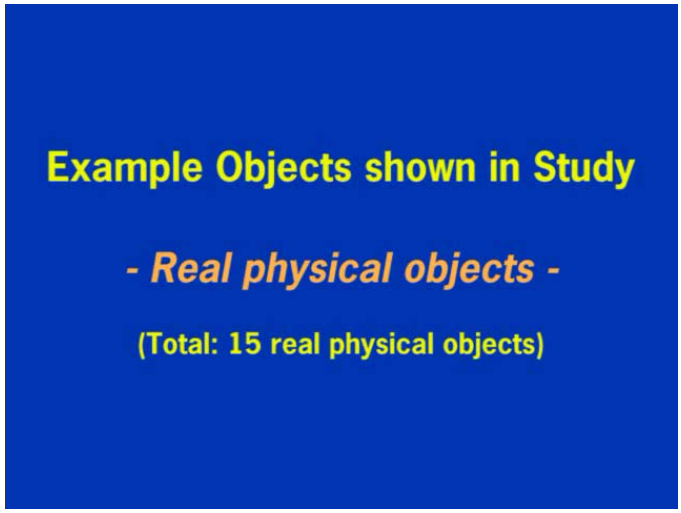
Procedure

- Participants were given an **instruction sheet** with examples
- Participants were shown images / videos **in random order**
- Video clips were displayed in a **loop**
  (Videos show slightly curved camera path around object)
- Participants had to decide:

"Is the central object real or virtual?"

- Choice was made by **keypress**
- **Correctness** of response and **reaction time** was recorded

Example Objects shown in Study Video



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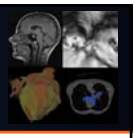
Results – Accuracy (1)

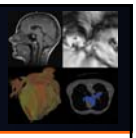


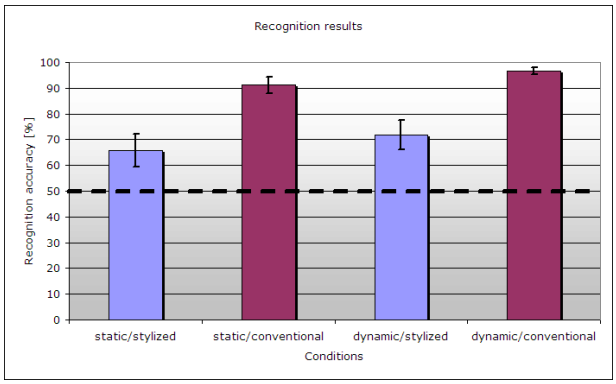
- Accuracy in **conventional** AR images: **94%**
- Accuracy in **stylized** AR images: **69%**

Significant main effect for AR rendering style ($F(1,15)=57.345$, $p<0.0001$)

- **No difference** between **still image** and **video** groups
- Accuracy for **virtual objects**: **86%**
- Accuracy for **real objects**: **77%**

Results – Accuracy (2)

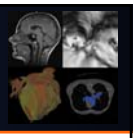




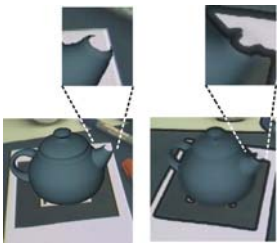
Dashed line indicates chance level.
Error bars represent standard error of the mean.

- Reduced accuracy in stylized AR mostly **driven by real objects**

Impact of Virtual Model Quality



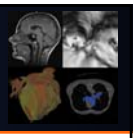
- **Graphical quality** of some models was not optimal
- Unnatural colors, errors in polygon mesh

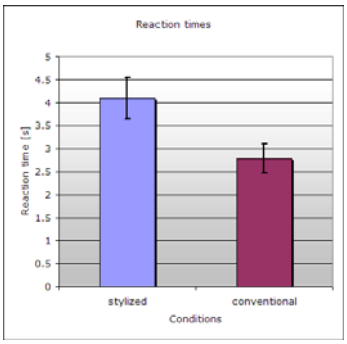


- Incomplete beak of teapot model
- Hint to participants that object is virtual

⇒ Graphical imperfections in virtual objects resulted in **higher recognition accuracy**

Results – Reaction Time



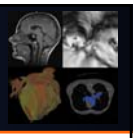


Error bars represent standard error of the mean.

- Average reaction time for **conventional** images: **2.8s**
- Average reaction time for **stylized** images: **4.0s**

$F(1,15)=17.059$, $p<0.001$

Overview



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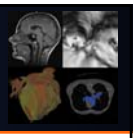
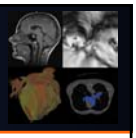
Conclusions



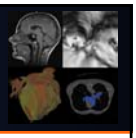
- Stylization **reduces detectable differences** between virtual and real objects
- **Equalized level of realism** is achieved
- Could indicate a **better "immersion"** or feeling of "presence"
- Clear results **despite low quality** of some virtual models

Future Work

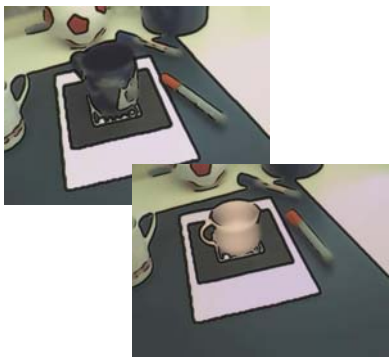


- Advanced studies in **more life-like** AR setting
- Evaluation of **task performance** in stylized AR
- Demonstration of **example applications** for stylized AR

The End



Questions?



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