

Stylized Augmented Reality for Improved Immersion



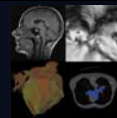
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WSI/GRIS, University of Tübingen (Germany)

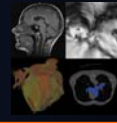
VR 2005
Mar 12-16th
Bonn-Germany

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WS GRIS Overview



- Stylized Augmented Reality
- Related Work
- Camera Image Filter
- Non-Photorealistic Renderer
- Results
- Recent Advances
- Conclusion



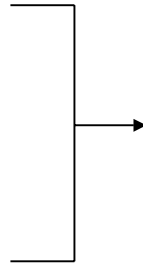
- Video see-through augmented reality



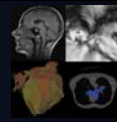
Camera image



Virtual object (OpenGL rendering)



Augmented video frame



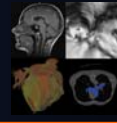
- Virtual objects displayed using a **standard real-time renderer**
 - Manually placed virtual light sources
 - Simple shading / illumination models
 - Rasterization artifacts
- Virtual scene elements tend to **look artificial**



Which one is real?

Real and virtual objects can easily be distinguished.

⇒ Negatively affects the user's feeling of "immersion".



- New approach:

Non-photorealistic display of **both** the camera image and virtual objects.

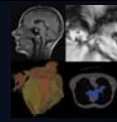
⇒ Adapted levels of realism



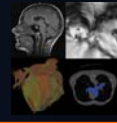
Conventional AR



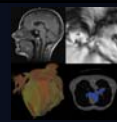
Stylized Augmented Reality



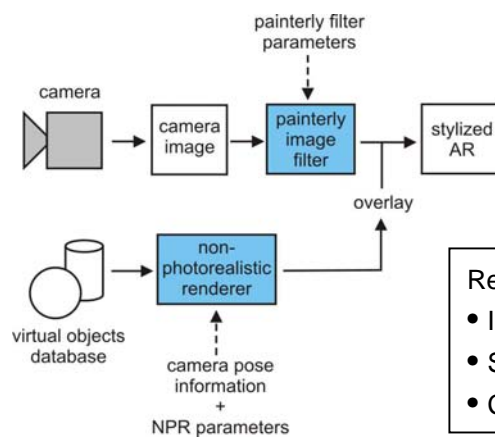
- Opposite approach: **Improving the realism** of virtual objects
 - Analysis of **illumination conditions**
[Kanbara and Yokoya 2002, Agusanto et al. 2003]
 - Addition of **shadowing**
[Haller et al. 2003, Sugano et al. 2003]
- **Non-photorealistic** virtual environments
[Klein et al. 2000]
- **Painterly rendering** for AR (only virtual objects)
[Haller and Sperl 2004]



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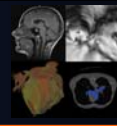
- Cartoon-like stylization of augmented reality images



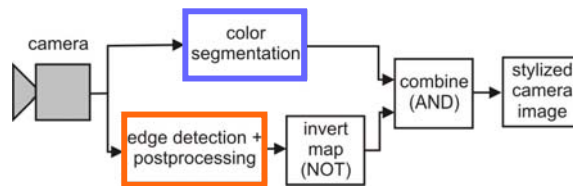
Requirements:

- Interactive frame rate
- Similar-looking output images
- Customizable

WS GR/S Camera Image Filter



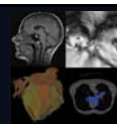
- Process camera image before virtual objects are rendered



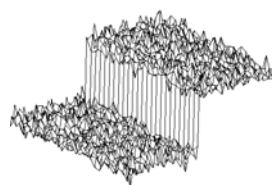
Create uniformly colored image regions ("color segmentation")

Draw silhouette outlines based on high-contrast edges

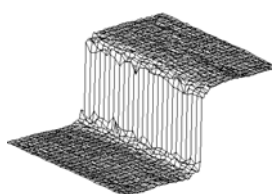
WS GR/S Color Segmentation



- Aim: Smooth similarly colored regions, but preserve high-contrast edges
- *Bilateral filtering* [Tomasi and Manduchi 1998]



Original pixel values



Filtered image



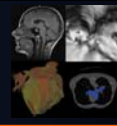
Original



Filtered
[Univ. Edinburgh]

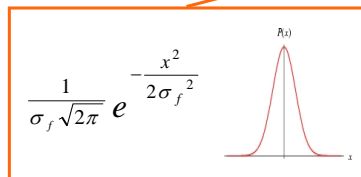
- Takes **spatial distance** and **signal difference** into account

ws GR/s Bilateral Filtering

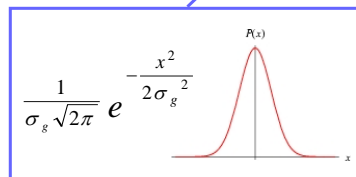


- Weighted summation of neighboring pixels

$$E(p) = \frac{1}{k(p)} \sum_{q \in \Omega} I(q) \cdot f(\|q - p\|) \cdot g(I(q) - I(p))$$



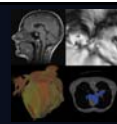
Emphasize closer pixels



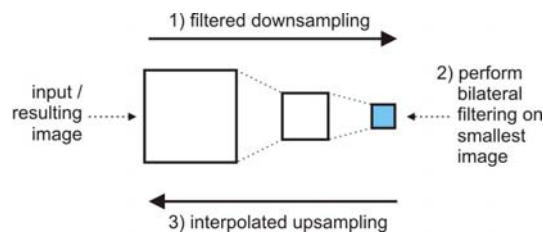
Emphasize similar colors

- Takes **spatial distance** and **signal difference** into account

ws GR/s Gaussian Pyramid

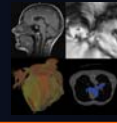


- Computation of bilateral filter in 3x3 or 5x5 neighborhoods
- **Too expensive** for real-time processing



- Build **Gaussian image pyramid**
- Perform bilateral filtering on top pyramid level (smallest image)

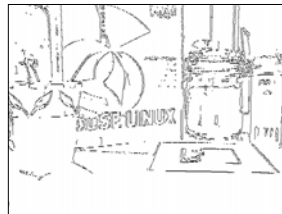
WS GR/S Edge Detection



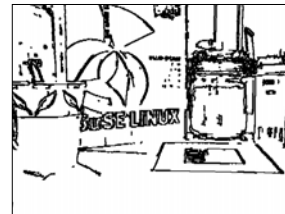
- **Canny edge detector** for finding coherent high-contrast edges [Canny 1986]
- Edge detection process controlled by thresholds t_1 and t_2
- **Morphological dilation** applied to binary edge image creates thicker silhouettes



Camera image

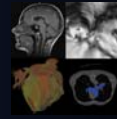


Edge detection result



Morphological dilation

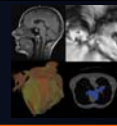
WS GR/S Camera Image Filter



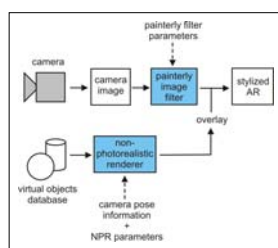
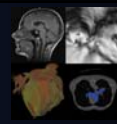
- First results (video)

Painterly Filter for Camera Image

Color Segmentation



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Overview of stylized AR

- **Cartoon-like rendering** of virtual objects
- Similarity to processed camera image
- Uniformly colored regions enclosed by thick silhouettes
- **Two-pass rendering** algorithm [Lander 2000]

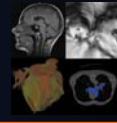


Conventional



Stylized

ws GR/s Discrete Shading (1)

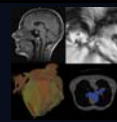


- Replace OpenGL shading in order to generate a discrete set of intensities
- Compute vertex intensity with diffuse lighting:

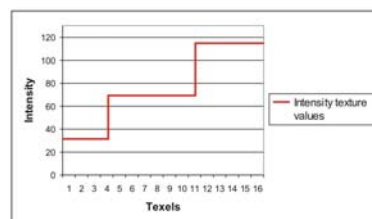
$$I_i = \max(\vec{n}_i \cdot \vec{L}, 0)$$

- Map intensities to discrete values
- One-dimensional shading texture stores intensity function

ws GR/s Discrete Shading (2)



- Vertex intensities are used as 1D texture coordinates
- Shading texture modulates base color of graphical model



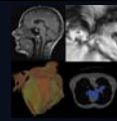
Shading texture example



Two intensity steps



Six intensity steps



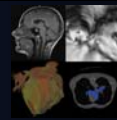
- Second pass: Render model as **wireframe**
- **Thick lines** are used for drawing
- **Front-facing** polygons are culled
- Adapted **depth test function**



Wireframe rendering of back-facing polygons

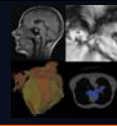


Silhouette lines pass depth test



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WS GRIS Implementation Details



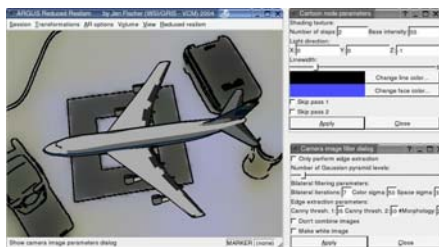
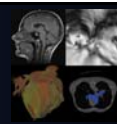
Base Technologies

- WSI / GRIS augmented reality framework **ARGUS**
- **ARToolKit** for video acquisition and camera tracking
- **OpenCV** library for image processing on the CPU
- **Qt** for graphical user interface
- **OpenGL** for rendering

Development Hardware

- Pentium 4 Xeon at 2.66 GHz, NVidia GeForce FX 6800 GT
- Firewire webcam delivering **640x480 pixels at 30 Hz**

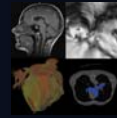
WS GRIS Experiments



Screenshot of Stylized AR software

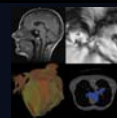
- Experiments with various example scenes
- Manual adaptation of algorithm parameters

- Measured **overall frame rates 10–14 fps**



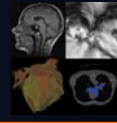
Stylized Augmented Reality

"Cartoon-like" Stylization
with virtual bench model

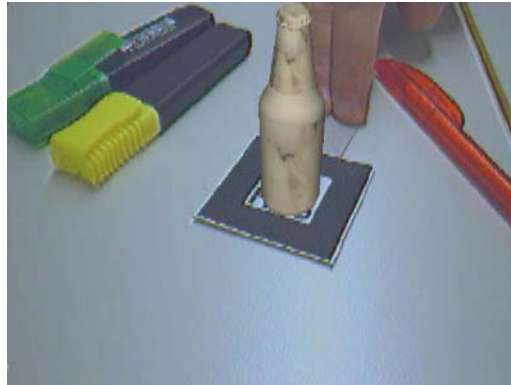


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WS GR/S Brush Stroke Stylization



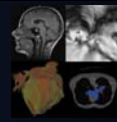
- Inspired by *pointillism* style of painting
- Real-time, CPU based algorithm



Stylized Augmented Reality

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WS GR/S Reality Tooning



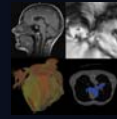
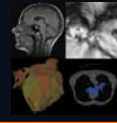
- Redesigned algorithm: **Pure postprocessing** approach
- Implementation on the GPU (OpenGL Shading Language)



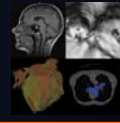
- Typically **more than 25 frames / sec.**
- Better visual quality

Stylized Augmented Reality

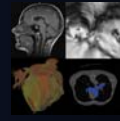
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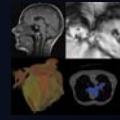
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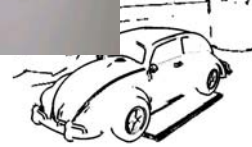
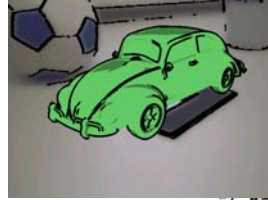
- New approach to generating augmented video streams
- "Stylized AR" paradigm can be realized with different types of stylization
- Can improve the user's feeling of "immersion"
- Possibly better AR experiences in fields like education, entertainment, and art
- Method is not suitable for applications requiring a high visual fidelity of the camera image, e.g. medical diagnosis and treatment



- User study on the effectiveness of the approach
- Development of new types of stylization and improvement of the existing algorithms
- Examination of possible application areas



Questions?



Acknowledgements:

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