IMPROVING ON-PATIENT MEDICAL DATA VISUALIZATION IN A MARKERLESS AUGMENTED REALITY ENVIRONMENT BY VOLUME CLIPPING

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AGENDA

- Introduction;
- Markerless Augmented Reality Environment;
- On-Patient Medical Data Visualization Based on Volume Clipping;
- Experimental Results and Discussion;
- Conclusion and Future Work;

Introduction

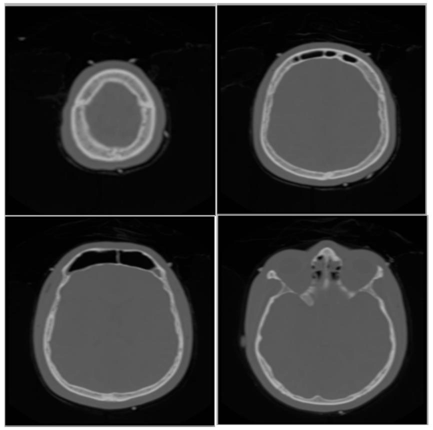
CONTEXT

- On-Patient Medical Data Visualization:

3D Data

shown as

2D Slices



which must be composed on

"Patient"

- Solution: Augmented Reality (AR)

CURRENT SCENARIO

- Bichlmeier et al. 2007:
  - Marker-Based AR;
  - Focus + Context Visualization;
- Macedo et al. 2014 (Previous Work at SVR):
  - Markerless AR;
  - Naive Virtual Content Superimposition;

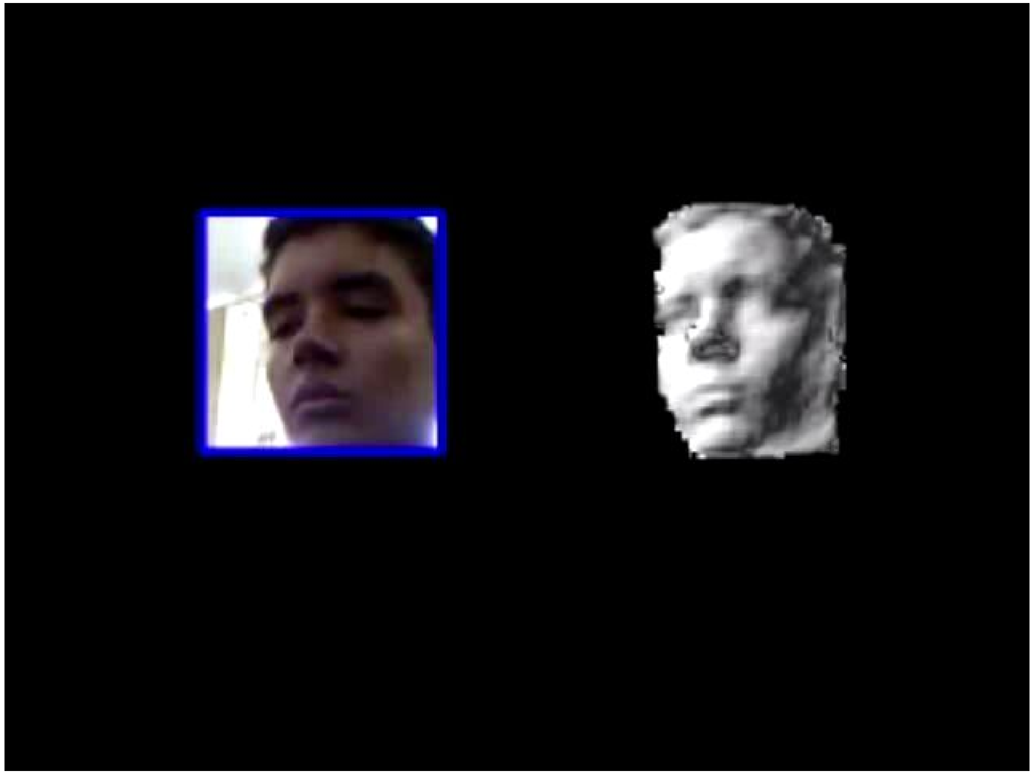
Contributions

- We propose new Focus + Context (F+C) visualization techniques to improve on-patient medical data visualization in a markerless AR environment based on volume clipping;
- Specifically, three methods are presented:
  - F+C visualization based on smooth contours;
  - F+C visualization based on visible background on CT and MRI data;

Markerless Augmented Reality Environment

3D Reference Model Reconstruction

- To track patient's movement without markers, a 3D reference model of the patient's ROI is generated with the KinectFusion algorithm;



Markerless Tracking

- After the placement of the medical data into the scene, markerless AR tracking can be started by using a real-time variant of the ICP algorithm;

On-Patient Medical Data Visualization Based on Volume Clipping

Volume Rendering

- Medical volume is rendered according to the named standard volume rendering techniques:
  - Front-to-back Direct Volume Rendering;
  - Single-pass Raycasting;
  - Stochastic Jittering;
  - Fast GPU-Based Tri-Cubic Filtering;
  - Empty-Space Skipping;
  - Early Ray Termination;
  - Pre-integrated Transfer Functions;
  - Blinn-Phong Illumination with on-the-fly gradient computation;
  - Volume Clipping based on clipping planes;

Integration into the Markerless AR Environment

- After medical volume rendering ($I_{medical}$), color frame buffer is loaded and sent to a shader to blend it with the RGB data (I_{real}) coming from RGB-D sensor;
- Blending is done by the following linear interpolation:

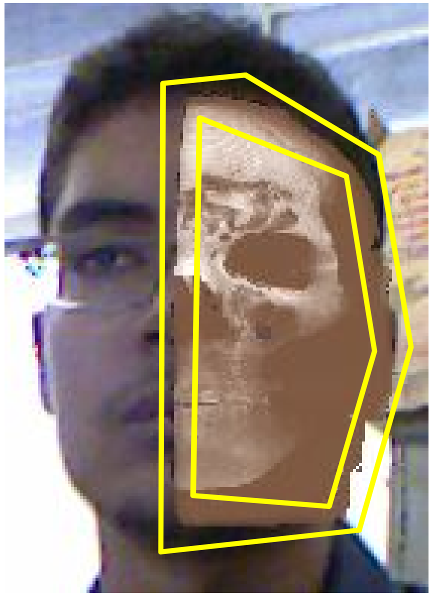
$$I_{final} = ß * I_{real} + (1 – ß) * I_{medical}$$

- Only valid for traditional F+C techniques (e.g. Bichlmeier et al.) and smooth contours;

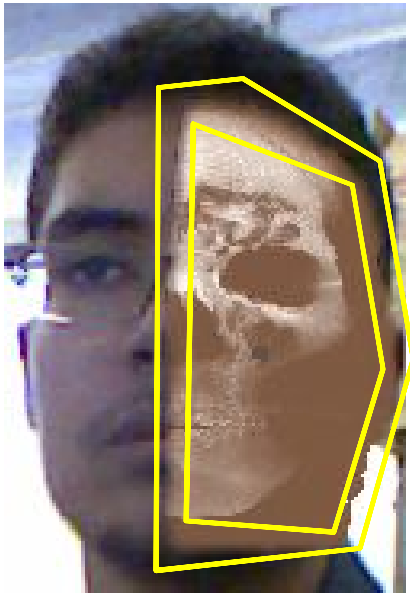
Focus + Context Visualization Based On Smooth Contours

- First Issue: Smooth transition between volume in focus region and the rest of the AR scene;

Without Smooth Contours



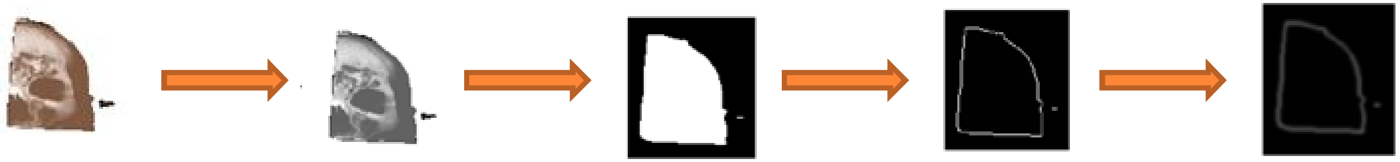
With Smooth Contours

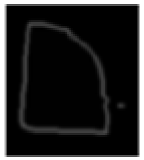


Focus + Context Visualization Based On Smooth Contours

- Pipeline Overview:

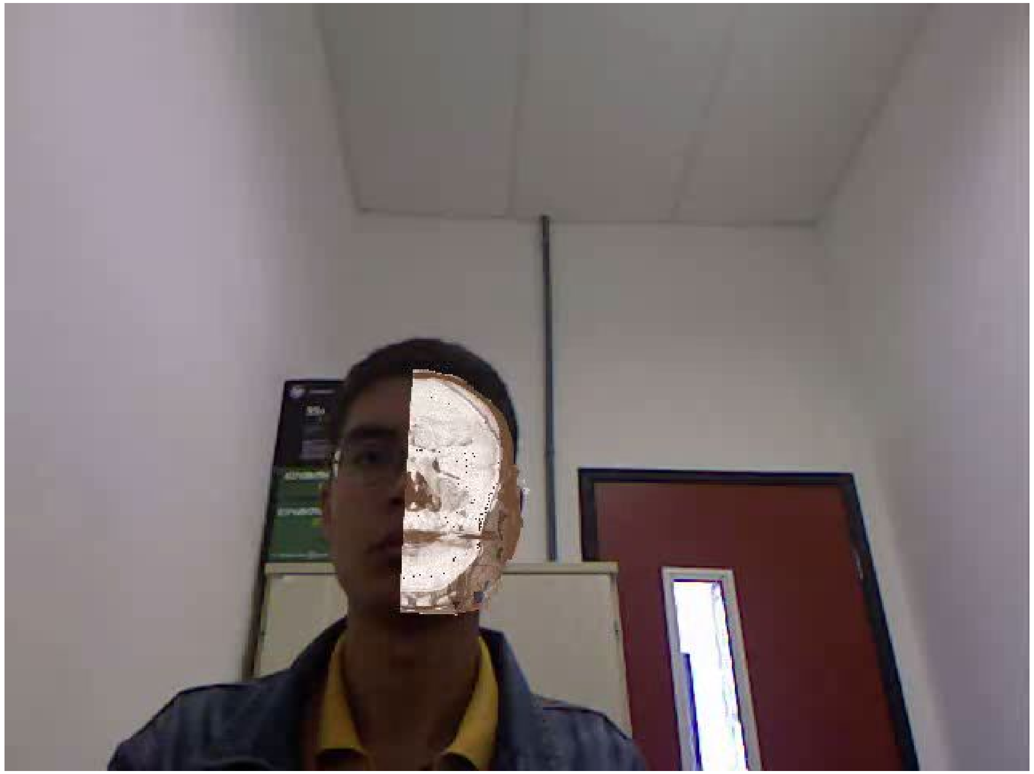
Medical Volume Color Image | Medical Volume Gray Image | Medical Volume Binary Image | Medical Volume Contours | Smooth Contours



ß =  $* \, w_c$

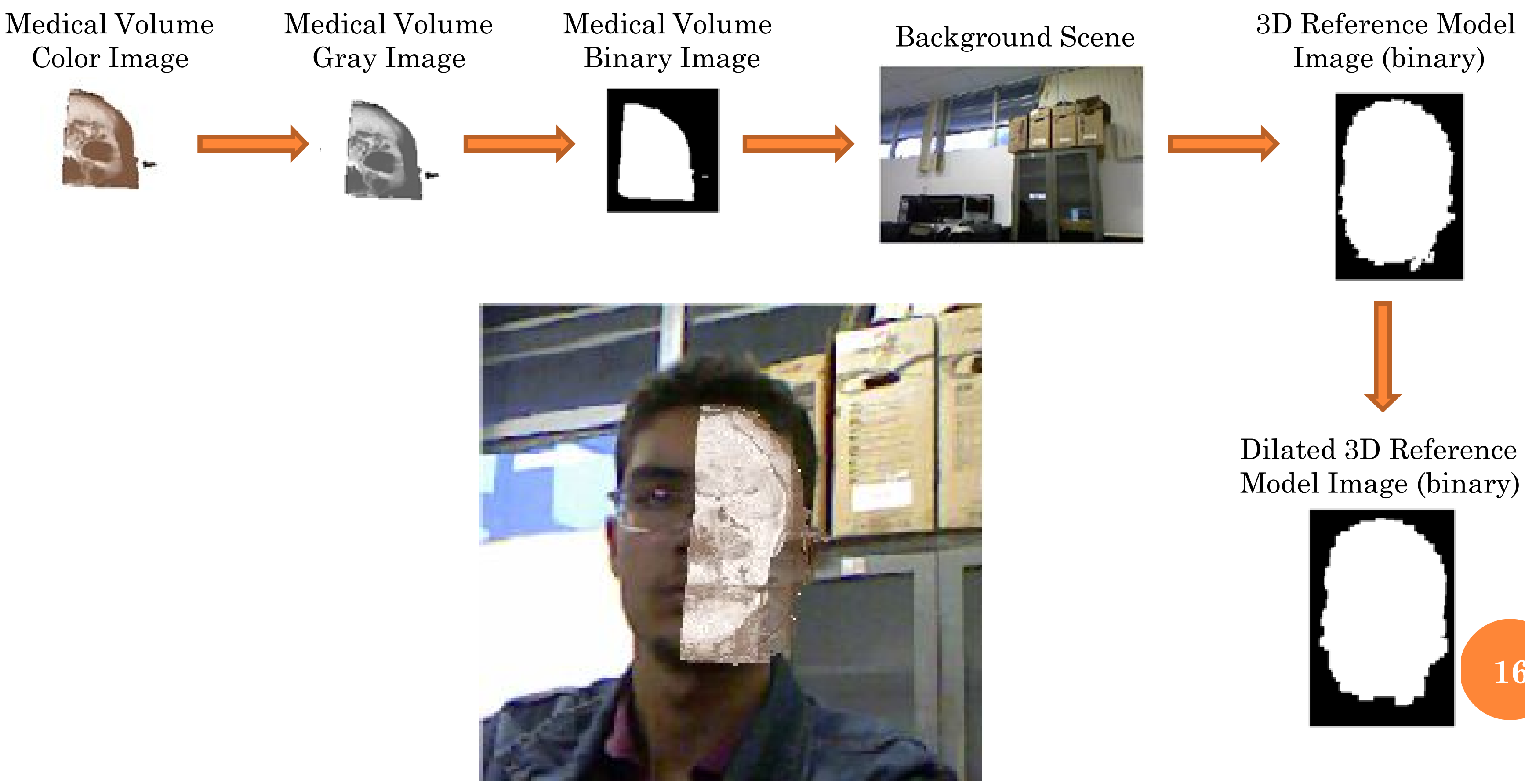
Focus + Context Visualization Based on Visible Background for CT Data

- Second issue: Show real background when the virtual one can be seen, depending on the transfer function chosen.



Focus + Context Visualization Based on Visible Background for CT Data

- Pipeline Overview:

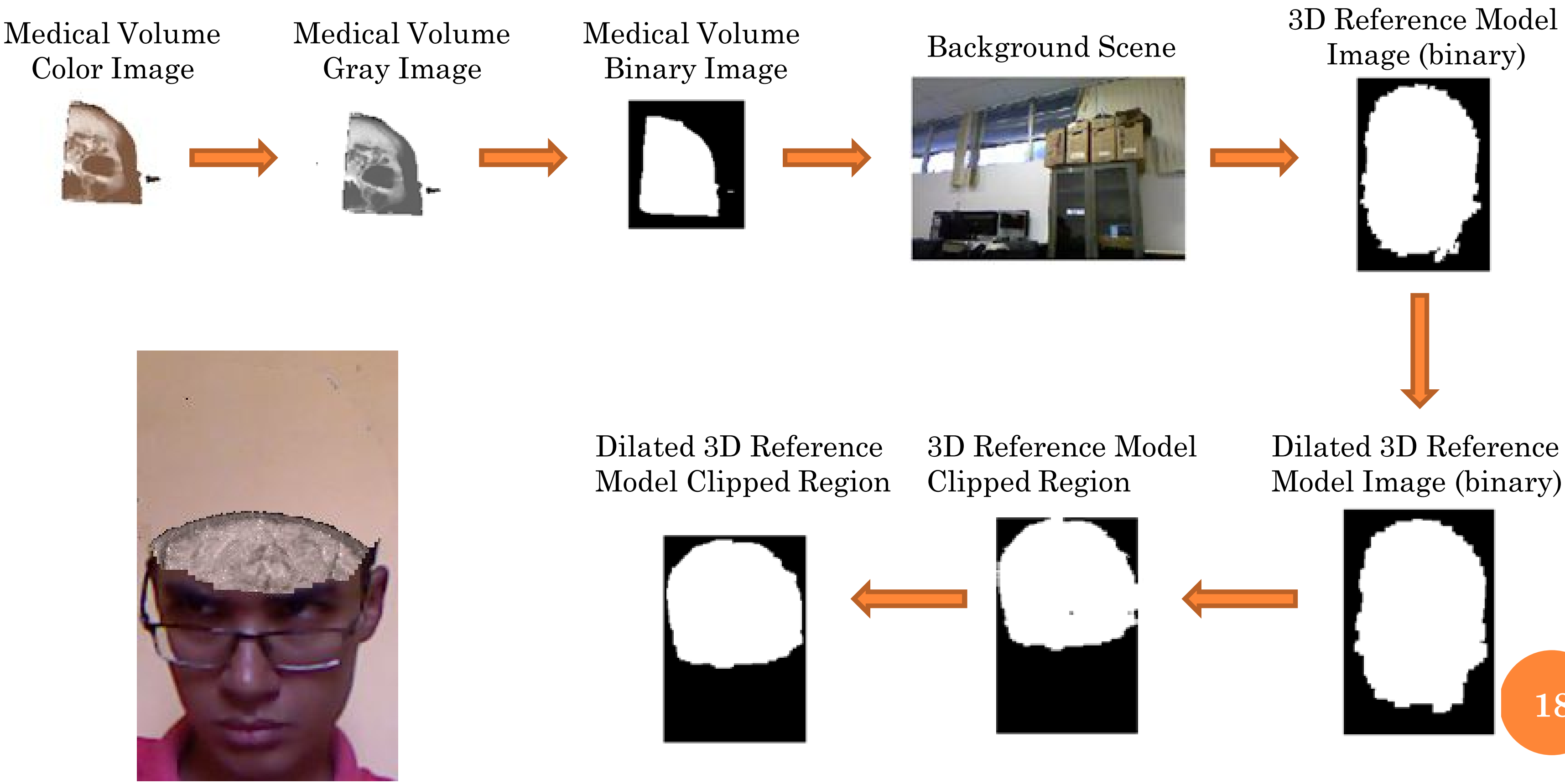


Focus + Context Visualization Based On Visible Background for MRI Data

- Third Issue: Show the real background scene when not only the volume is clipped, but also the patient's region of interest.

Focus + Context Visualization Based On Visible Background for MRI Data

- Pipeline Overview:



Experimental Results and Discussion

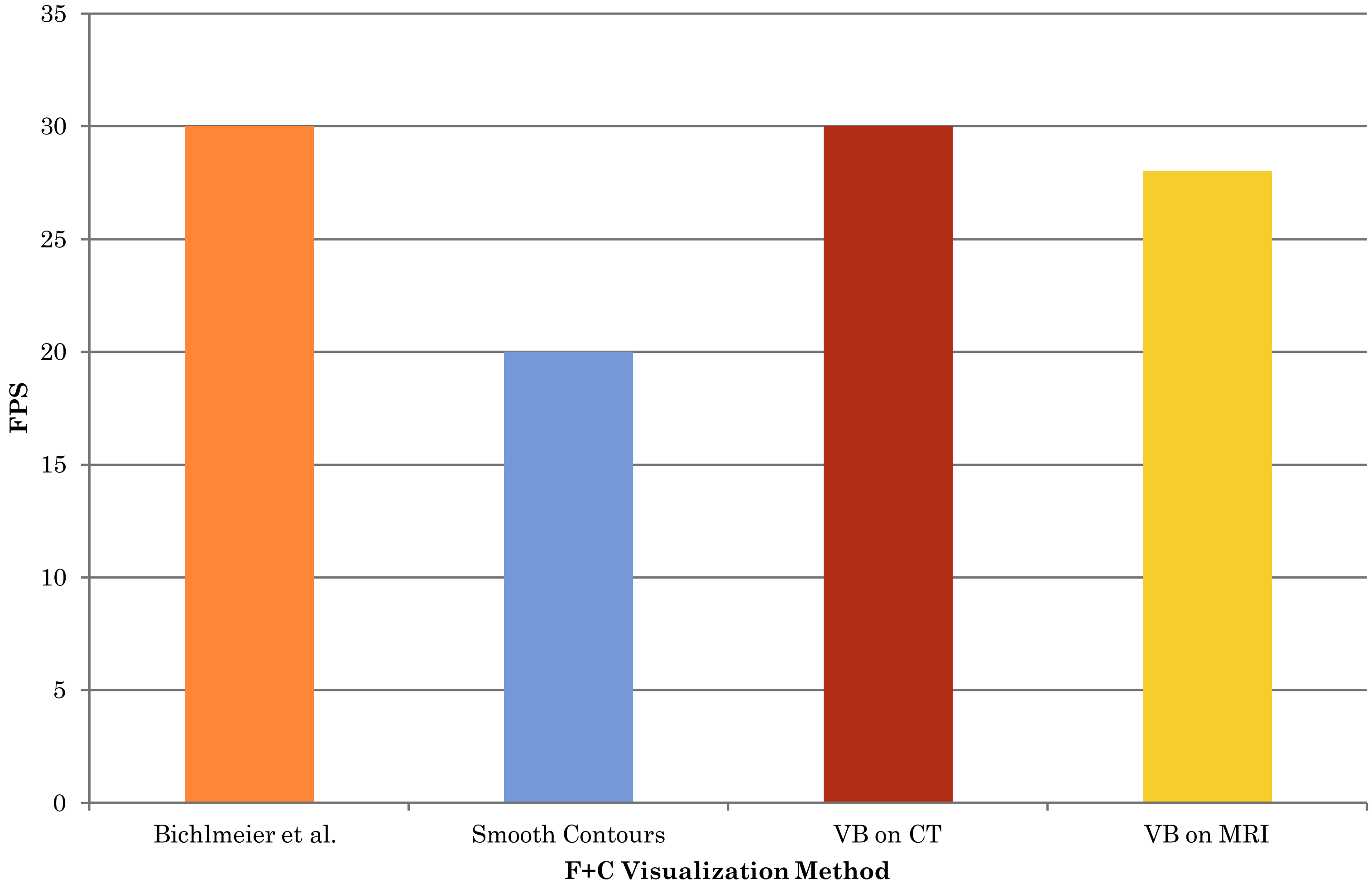
Experimental Setup

- For all tests we used an Intel® Core™ i7-3770K CPU @3.50Ghz, 8GB RAM, NVIDIA GeForce GTX 660;
- Medical dataset:
  - CT volumetric data of a head from the Visible Human Project of resolution 128x256x256;
  - MRI volumetric data of a head from the MRI Head available in Volume Library of resolution 256x256x256;
- Reference human head is reconstructed with the KinectFusion algorithm using a grid with volume size of 70cmx70cmx140cm and resolution of 512x512x512

Performance Evaluation

- 3D reference model reconstruction runs at 30 frames per second (FPS);
- 3D reference model is generated in ~15 seconds;
- Registration between medical data and reference model:
  - Coarse registration (i.e. pose + scale) takes 60 milliseconds;
  - Fine registration (i.e user refinement) takes about 10 seconds;
- Markerless live tracking and volume rendering run at 30 FPS;

Performance Evaluation



Visual Quality Evaluation

- Occlusion handling:

VISUAL QUALITY EVALUATION

- Adjusting Smooth Contours:

$w_c = 0$

$w_c = 2$

$w_c = 4$

Visual Quality Evaluation

- Adjusting Visible Background on CT Data:

$w_{grayLevel} = 0$

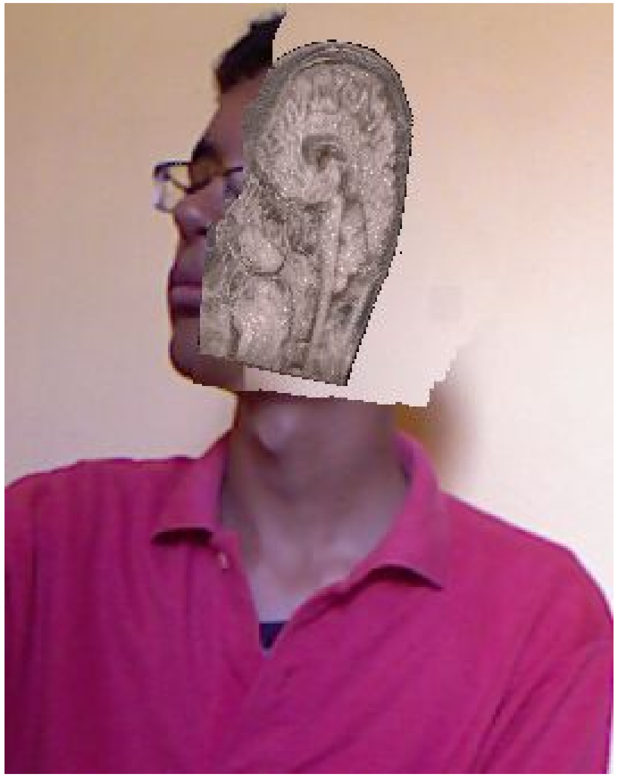
$w_{grayLevel} = 0.5$

$w_{grayLevel} = 0.75$

$w_{grayLevel} = 1$

Visual Quality Evaluation

- Interactions with Visible Background on MRI Data:



Conclusions and Future Work

Final Considerations

- Conclusions:
  - We have improved on-patient medical data visualization by using volume clipping;
  - All the methods proposed run in real-time;
- Future Work:
  - Improve realism by integrating real local and global illumination effects into the markerless environment (Image-Based Lighting);
  - Support user non-rigid interactions (Real-Time Non-Rigid Registration);
  - Improve tracking by supporting relocalization (Robust Rigid Registration);

ACKNOWLEDGMENTS

- We are grateful to:
  - PCL project – for providing the open-source implementation of the KinectFusion algorithm;
  - Anonymous reviewers – for their valuable comments and suggestions;
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Thank You!

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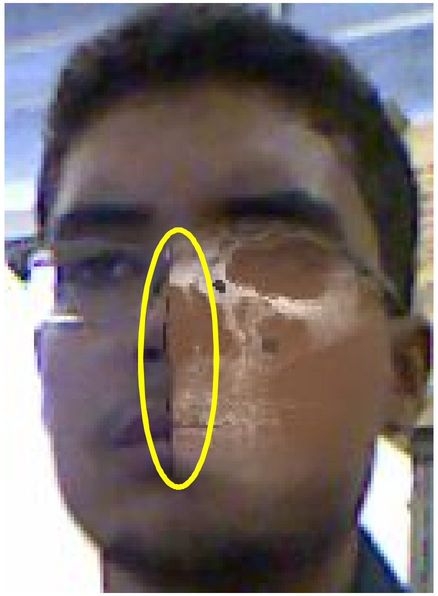
Accuracy Evaluation

- 3D reference model reconstruction – 10mm;
- Live tracking – 2mm (not incremental);
- Registration between medical data and reference model – semi-automatic;

FOCUS + CONTEXT VISUALIZATION BASED ON SMOOTH CONTOURS

- This method can be easily integrated with state-of-the-art focus+context visualization techniques:

Bichlmeier et al.
2007



Bichlmeier et al. 2007 +
Smooth Contours