Development of a User-Centered Virtual Liver Surgery System

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Global Contributor to Eco-Techno-Humanopia
Agenda

- Introduction
  - Background
  - Objectives of the Study
- Use Scenario & Demo of Dr. Liver
- Performance evaluation
- Future Study
Values of 3D Virtual Liver Surgery System

- Vascular structure
- Location & size of tumor
- Segmentation of the liver

Analytical Visualization

Quantitative Assessment

Safe & Rational Surgery

- Volumetry of the liver
- Volumetry of the remnant and/or graft

Liver = 1427.2 ml
Resected = 338.3 ml
Removal = 24.7%
# Virtual Surgery Systems: Generic

<table>
<thead>
<tr>
<th>Country</th>
<th>System features</th>
</tr>
</thead>
</table>
| Korea  | ● 3D visualization  
|         | ● Measurement  
|         | ● Options  
|         | ✓ Colon & polyps  
|         | ✓ Cardiac Ca  
|         | ✓ Vessel  
|         | ✓ Brain angio  |
| Japan  | ● 3D visualization  
|         | ● Measurement  
|         | ● Options  
|         | ✓ Colon  
|         | ✓ Cardiac Ca  
|         | ✓ Vessel  |
| Germany | ● Oncology  
|         | ✓ PET & CT segmentation (extraction)  
|         | ✓ CT Lung CAD  
|         | ✓ Colonography  
|         | ● Cardiology  
|         | ✓ Vascular  
|         | ✓ Cardiac  
|         | ✓ Ca Scoring  
|         | ● Neurology  
|         | ✓ PET evaluation  
|         | ✓ Perfusion CT  |
| Swiss  | ● 3D visualization  
|         | ● Measurement  
|         | ● Options  
|         | ✓ Custom plugins  
|         | ✓ iPhone, iPad compatible  |
Liver Extraction: Manual & Semi-Automatic

Voxar 3D

Rapidia

Syngo.via

OsiriX
<table>
<thead>
<tr>
<th>Synapse Vincent (Fujifilm)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System features</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Specialized liver functions</td>
</tr>
<tr>
<td>✓ Liver extraction</td>
</tr>
<tr>
<td>✓ Vessel analysis</td>
</tr>
<tr>
<td>✓ Segmentation</td>
</tr>
<tr>
<td>✓ Volumetry</td>
</tr>
<tr>
<td>✓ Surgery planning</td>
</tr>
</tbody>
</table>
Visia™ Liver-Distant Services

- MeVis Medical Solutions AG
- LiverAnalyzer & LiverViewer developed using MeVisLab
- Analysis services
  - Segmentation of the liver, veins, biliary system, and tumors
  - Volumetric data for both remnant and/or graft
  - Vascular territory evaluation
  - Virtual resection options
Surgery Planning – Oncological Case

This report is for demonstration purposes only!

Patient: Demo_Tumor
ID: XYZ123

Last selected object group: Cut1, Extended Right Hemihepatectomy, PV and HA (of Cut1, Extended Right Hemihepatectomy).

LiverAnalyzer

Not For Sale!
Objectives of the Study

Development of a user-friendly virtual liver surgery system: **Dr. Liver**

1. Specialized functions to liver surgery
2. Intelligent decision support information
3. Intuitive, user-friendly interface
4. Acceptable information processing time
Use Scenario: System Overview

Liver extraction  Vessel extraction  Tumor extraction  Liver segmentation  Surgery planning

Entire processing time: **25 ~ 30 min**
Use Scenario: Liver Extraction

S1(A). Denoising
- Noise removing in CT images

S2(SA). Initial contour generation
- Multiple seed points selection on liver using the mouse
- Initial liver contour generation using fast marching level set method

S3(A). Liver contour refinement
- Liver contour refinement using threshold level set method
- Liver contour verification
- Hole filling and liver surface smoothing
- Unwanted part elimination

S4(A). Prost processing

Total 5 min

1 min 1 min 2 sec 3 min
Demo: Liver Extraction
Demo: SLV Estimation
Use Scenario: Vessel Extraction

S1(M). Seed point selection

S2(M). Interactive threshold interval identification

S3(A). Vessel extraction

S4(A). Prost processing

- Single seed point selection on vessel for region growing using the mouse
- Threshold interval identification using slider bars
- Vessel extraction using region growing method
- Extracted vessel verification
- Hole filling

Total 5 ~ 10 min
Demo: Vessel Extraction
Use Scenario: Tumor Extraction

S1(M). Seed point selection

S2(M). Interactive threshold interval identification

S3(A). Tumor extraction

S4(A). Prost processing

• Multiple seed point selection on tumor using the mouse
• Threshold interval identification using slider bars
• Tumor extraction using threshold level set method
• Diagnosis verification: false identification, missing
• Hole filling & smoothing

Total 5 min

10 sec 10 sec 1 min 3 min
Demo: Tumor Extraction
Use Scenario: Segmentation

- Cutting point selection using the mouse for cutting portal vein
- Portal vein branch selection using the mouse for segmentation
- Liver segmentation
- Segment result verification
- Coloring
- Volume estimation for each segment

1 min 1 min 1 min

Total 3 min
Demo: Liver Segmentation
Use Scenario: Surgery Planning

S1(M). Surgery method determination

• Liver surgery method (transplantation & resection) selection based on volume estimation and vessel analysis results

S2(SA). Optimal surgery planning support

• Optimal resection location, surface, and angle for surgery planning
• Safety margin and affected venous branch identification
• Real-time volume calculation of remaining liver parenchyma
Demo: Surgery Planning

Liver = 1421.2 ml
Resected = 1421.2 ml
Remnant = 0%
## Comparison with OsiriX: Liver Extraction

<table>
<thead>
<tr>
<th>Method</th>
<th>Dr. Liver</th>
<th>OsiriX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid method</td>
<td>Region growing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2D Auto</td>
<td>2D Auto &amp; Editing</td>
</tr>
<tr>
<td>Procedure</td>
<td>• 10~15 seed points</td>
<td>• Liver extraction slice by slice</td>
</tr>
<tr>
<td></td>
<td>• Initial liver contour detection</td>
<td>• One seed point for each slice</td>
</tr>
<tr>
<td></td>
<td>• Contour refinement</td>
<td>• Manual editing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Liver extraction based on entire volume data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• One single seed point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Manual editing</td>
</tr>
</tbody>
</table>

### Virtual Liver Resection and Volumetric Analysis of the Future Liver Remnant using Open Source Image Processing Software

Joost R. van der Vorst · Ronald M. van Dam ·
Rogier S. A. van Stiphout · Maartje A. van den Broek ·
Ilona H. Hollander · Alfons G. H. Kessels · Cornelis H. C. Dejong

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**Abstract**

Background After extended liver resection, a remnant liver that is too small can lead to postresection liver failure. To reduce this risk, preoperative evaluation of the future liver remnant volume (FLRV) is critical. The open-source OsiriX® PAC software system can be downloaded for free and used by nonradiologists to calculate liver volume using a stand-alone Apple computer. The purpose of this study analyzed by three observers. Two surgical trainees measured the total liver volume, resection volume, and tumor volume using OsiriX®, and a radiologist measured these volumes using CT scanner-linked Aquarius iNtuition® software. Resection volume was correlated with prospectively determined resection weight, and differences in the measured liver volumes were analyzed. Interobserver variability was assessed using Bland–Altman plots.
Performance Comparison: Visual Inspection

- Performance: **Hybrid** > 2D Auto > 3D Auto

<table>
<thead>
<tr>
<th>Manual (Reference)</th>
<th>Hybrid</th>
<th>2D Auto</th>
<th>3D Auto</th>
</tr>
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<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td><img src="image5.png" alt="Image" /></td>
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<td><img src="image15.png" alt="Image" /></td>
<td><img src="image16.png" alt="Image" /></td>
</tr>
</tbody>
</table>

False positive
False negative
Performance Comparison: Visual Inspection

- Performance: **Hybrid** > 2D Auto > 3D Auto

<table>
<thead>
<tr>
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<th>OsiriX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2D Auto</td>
<td>3D Auto</td>
</tr>
<tr>
<td><strong>1st trial</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D output</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>Volume (ml)</td>
<td>(1218.0)</td>
<td>(1221.1)</td>
<td>(1279.6)</td>
</tr>
<tr>
<td><strong>2nd trial</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D output</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
<td><img src="image7" alt="Image" /></td>
</tr>
<tr>
<td>Volume (ml)</td>
<td>(1234.0)</td>
<td>(1232.9)</td>
<td>(1278.8)</td>
</tr>
</tbody>
</table>
Performance Comparison: Objective Measures

- **Accuracy**: Hybrid $> 2D$ Auto & Editing $\sim 3D$ Auto & Editing
- **Reliability**: Hybrid $\cong 2D$ Auto & Editing $> 3D$ Auto & Editing
- **Efficiency**: Hybrid $> 3D$ Auto & Editing $> 2D$ Auto & Editing

<table>
<thead>
<tr>
<th>Method</th>
<th>Liver volume (ml)</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td>Difference*</td>
</tr>
<tr>
<td>Hybrid</td>
<td>4.2</td>
<td>8.9</td>
</tr>
<tr>
<td>OsiriX 2D Auto &amp; Editing</td>
<td>5.9</td>
<td>31.5</td>
</tr>
<tr>
<td>OsiriX 3D Auto &amp; Editing</td>
<td>15.5</td>
<td>28.7</td>
</tr>
</tbody>
</table>
Future Work

- **Interactive segmentation**
  - More functional
  - More interactive w/ surgeon

- **Deformable cutting plane**
  - More flexible
  - More adaptive to segmentation

- **Clinical application & usability testing**
  - Efficient
  - Effective
  - Satisfactory
Thank you for your attention!