



Development and Usability Testing of Dr. Liver, a User-Centered Virtual Liver Surgery Planning System

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South Korea

Members



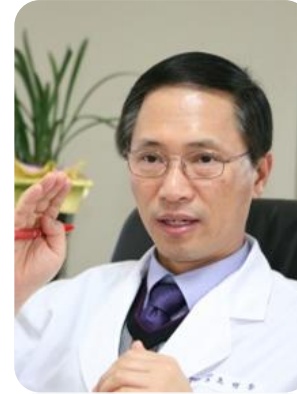
POSTECH
IME Department



전북대학교병원
CHONBUK NATIONAL UNIVERSITY HOSPITAL



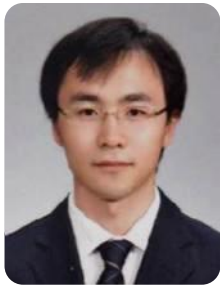
Heechon You



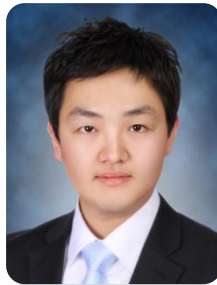
Biakhwan Cho



Heechul Yu



Xiaopeng Yang



Younggeun Choi



Wonsup Lee



Jihyun Kim



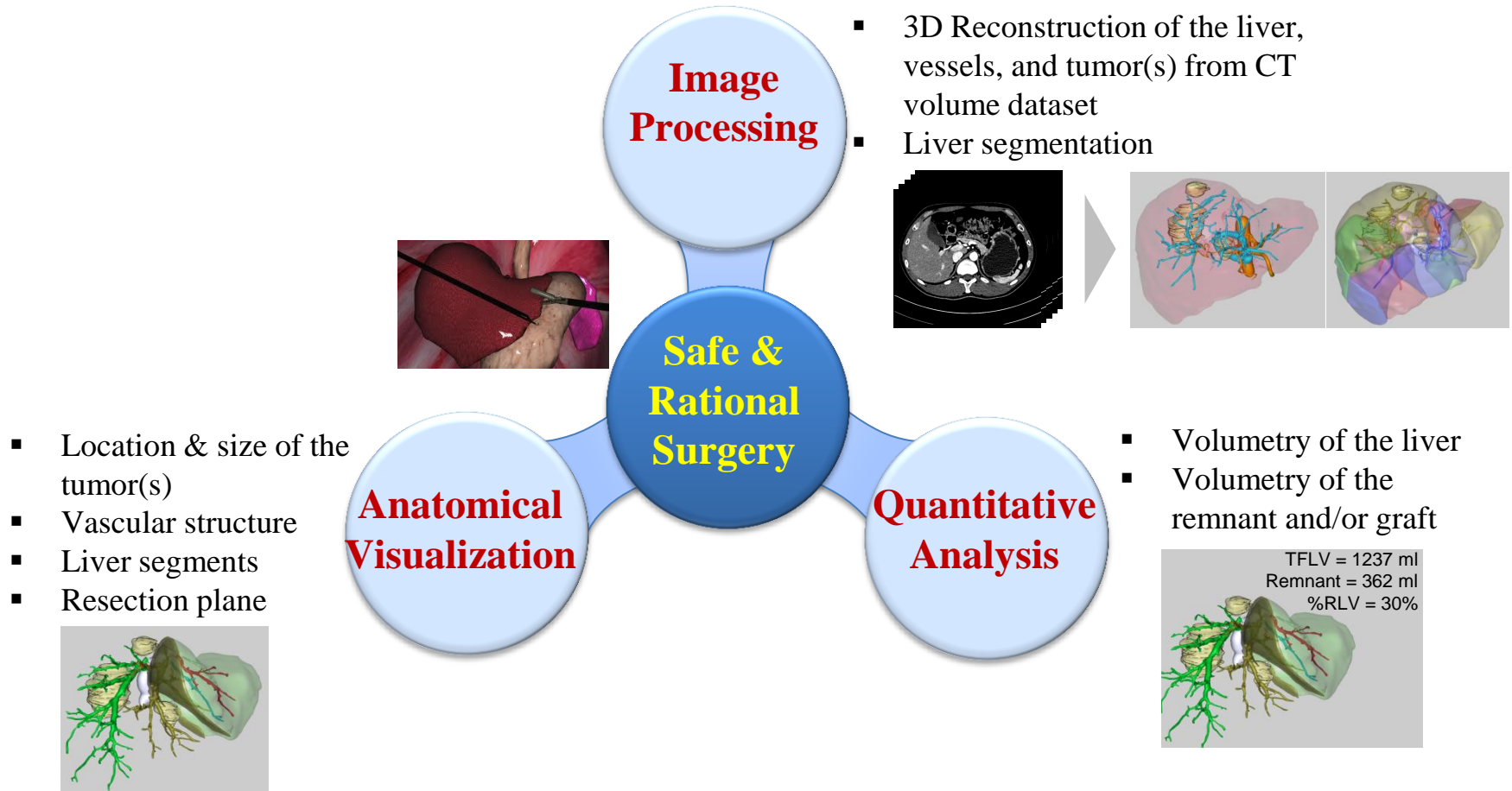
INDUSTRIAL AND MANAGEMENT
ENGINEERING, POSTECH

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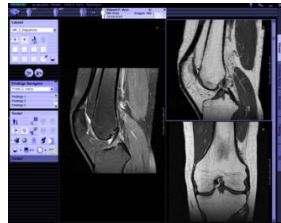





- **Introduction**
 - Background
 - Objectives of the Study
- **Virtual Liver Surgery Planning System Development**
- **Usability Testing**
- **Discussion**

Virtual Liver Surgery Planning System?

- A system which assists surgeons in **preoperative planning** for liver **resection** and **transplantation**



Generic Virtual Surgery Systems

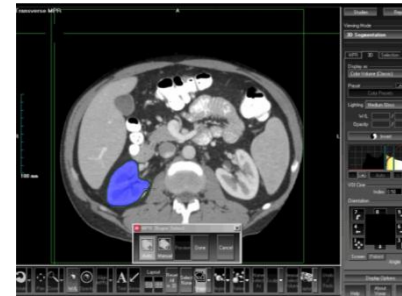
	Rapidia (Infinit)	Voxar 3D (Barco ⇒ Toshiba)	Syngo.via (Simense)	OsiriX (Freeware - Pixmeo)
System				
Country	 Korea	 Japan	 Germany	 Swiss
System features	<ul style="list-style-type: none"> ● 3D visualization ● Measurement ● Options <ul style="list-style-type: none"> ✓ Colon & polyps ✓ Cardiac Ca ✓ Vessel ✓ Brain angio 	<ul style="list-style-type: none"> ● 3D visualization ● Measurement ● Options <ul style="list-style-type: none"> ✓ Colon ✓ Cardiac Ca ✓ Vessel 	<ul style="list-style-type: none"> ● Oncology <ul style="list-style-type: none"> ✓ PET & CT segmentation (extraction) ✓ CT Lung CAD ✓ Colonography ● Cardiology <ul style="list-style-type: none"> ✓ Vascular ✓ Cardiac ✓ Ca Scoring ● Neurology <ul style="list-style-type: none"> ✓ PET evaluation ✓ Perfusion CT 	<ul style="list-style-type: none"> ● 3D visualization ● Measurement ● Options <ul style="list-style-type: none"> ✓ Custom plugins ✓ iPhone, iPad compatible

Generic Virtual Surgery Systems: Limitations

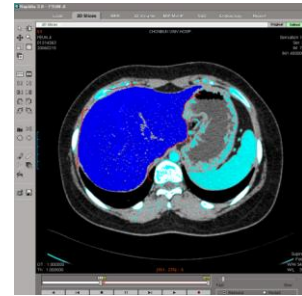
- Lack of functions **specialized for liver surgery planning**, such as **liver segmentation** and **surgical resection simulation**
- Liver extraction
 - Manual drawing
 - Liver contour manually traced slice by slice
 - Time demanding: **more than 30 min** for a CT dataset of 200 slices with a thickness of 1 mm
 - Semi-automatic
 - Simple region growing method provided
 - **Heavy manual editing** required due to false extraction

⇒ **Cumbersome** to users

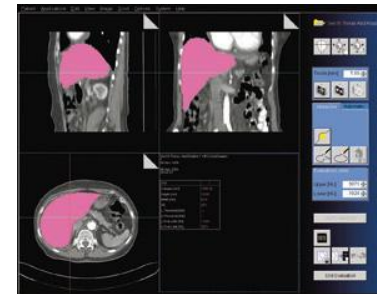
Voxar 3D



Rapidia




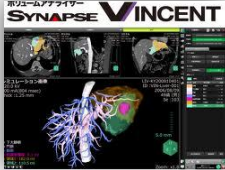

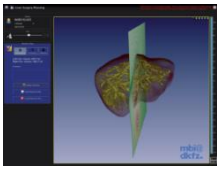




Syngo.via



OsiriX



Specialized Virtual Liver Surgery Planning Systems

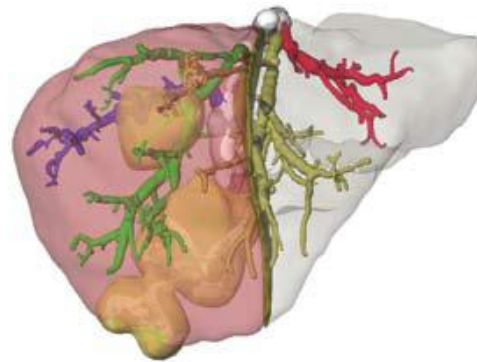
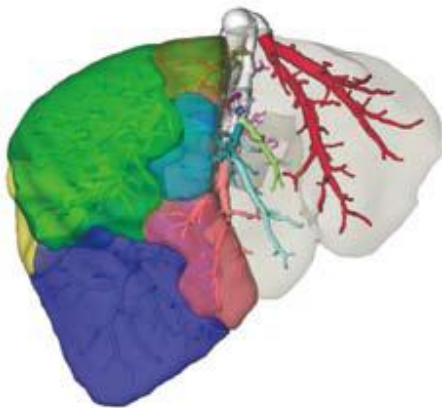
	MeVis Distant Service (MeVis)	Synapse Vincent (Fujifilm)	IQQA Liver (EDDA)	Mint Liver (Mint Medical & German Cancer Research Center)
System				
Country	 Germany	 Japan	 USA China	 Germany
System features	<ul style="list-style-type: none"> ● Segmentation of the liver, veins, biliary system, and tumors ● Volumetric data for both remnant and/or graft ● Vascular territory evaluation ● Virtual resection options 	<ul style="list-style-type: none"> ● Liver extraction ● Vessel analysis ● Segmentation ● Volumetry ● Surgery planning 	<ul style="list-style-type: none"> ● Segmentation of the liver, lobes, vessels, and lesion ● Volumetry ● Calculation of 3D distances, margins, and diameters ● Virtual knife control 	<ul style="list-style-type: none"> ● Integration in the existing software platform ● Automatic liver analysis <ul style="list-style-type: none"> ✓ Visualization ✓ Volumetry ● Definition of resection strategies

MeVis Distant Services

- Provided by MeVis Medical Solutions AG, Germany
- 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

Limitation:

- LiverAnalyzer **not for sale**



Surgery Planning – Oncological Case

Liver analysis report (viewed by LiverViewer)

This report is for demonstration purposes only!

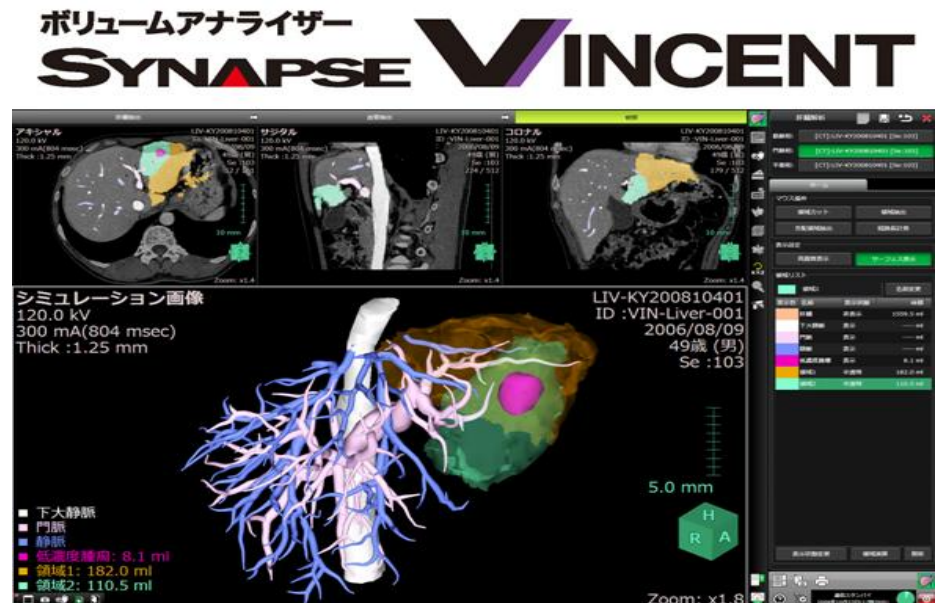
The screenshot displays the MeVis Medical Solutions interface. At the top, there are navigation tabs for 'Anatomy', 'Risk Analysis', and 'Resection Proposals'. Below these, a sub-menu shows 'Cut1, Extended Right Hemihepatectomy' and 'Cut2, Local Resection'. The main window shows a 3D model of a liver with a network of blue and orange vessels. The patient information is 'Patient: Demo_Tumor ID: XYZ123'. A vertical toolbar on the right contains icons for navigation and information. At the bottom, a status bar reads: 'Last selected object group: Cut1, Extended Right Hemihepatectomy, PV and HA (of Cut1, Extended Right Hemihepatectomy)'.

Limitation:

- Difficult to **cross-check** the **accuracy** of the analysis results since CT images are **not** provided

Synapse Vincent

- Developed by Fujifilm, Japan
- Functions provided
 - Liver extraction
 - Vessel analysis
 - Liver segmentation
 - Volumetry
 - Surgery planning



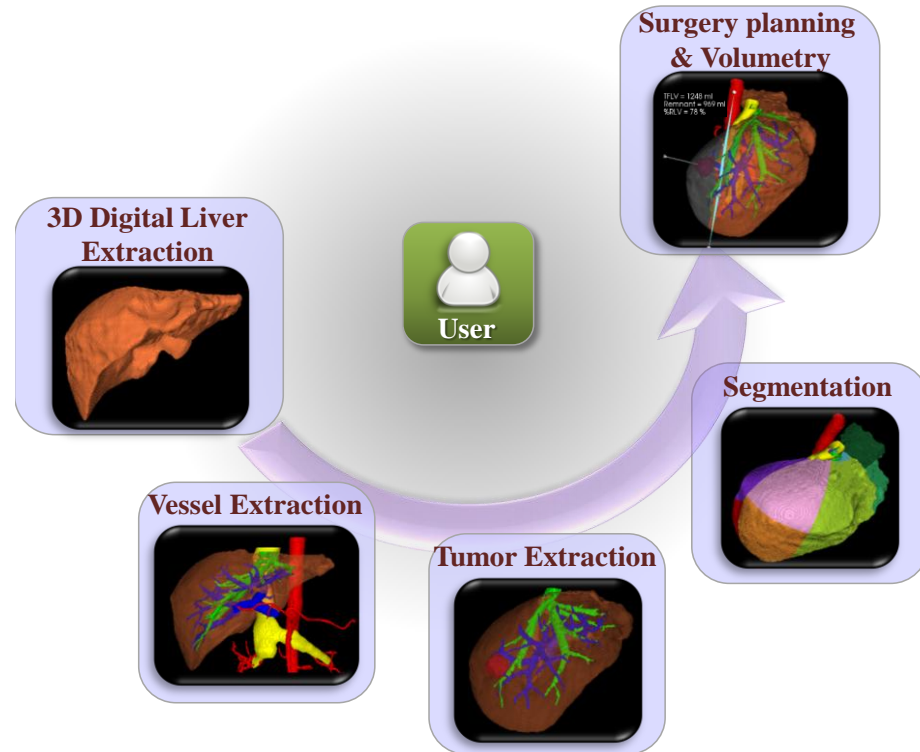
Limitations:

- Expensive
- More user-friendly UI needed
- Manual drawing of vessels required
 - ⇒ Cumbersome to users

Research Objectives

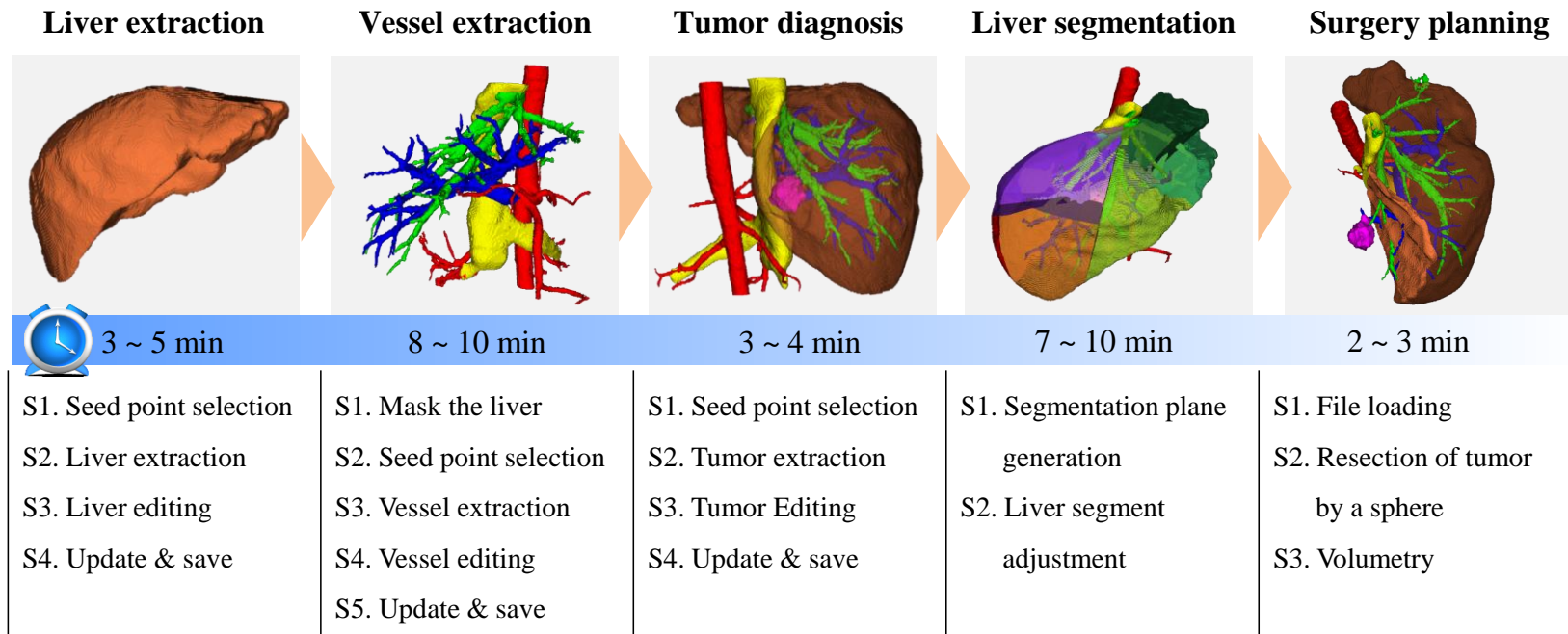
Development and Usability Testing of **Dr. Liver**, a User-Centered Virtual Liver Surgery Planning System

1. Functions specialized to liver surgery
2. Decision support information
3. Intuitive, user-friendly interface
4. Acceptable processing time



Use Scenario Development

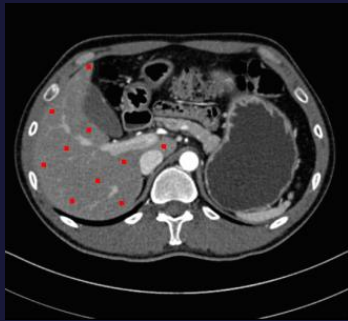
- A use scenario consisting of hierarchical tasks was developed based on
 - Interviews with surgeons
 - Benchmarking of commercialized systems
 - Literature survey
 - Questionnaires



Entire processing time: 20 ~ 30 min

Use Scenario: Liver Extraction Module

S1(M). Seed point selection



< 1 min

- **Multiple seed points selection** on the liver using the mouse

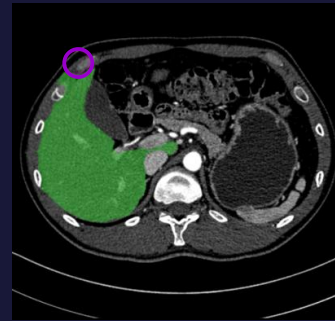
S2(A). Liver extraction



1 min

- **Liver extraction** using the proposed hybrid method
- **Liver contour verification**

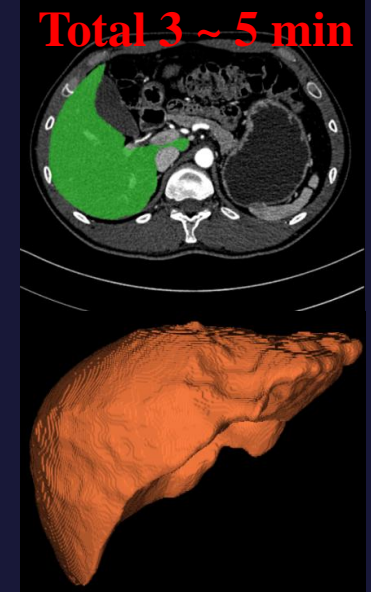
S3(M). Liver Contour editing



1 min

- **Liver contour editing** using a scalable editing circle

S4(A). Update & save

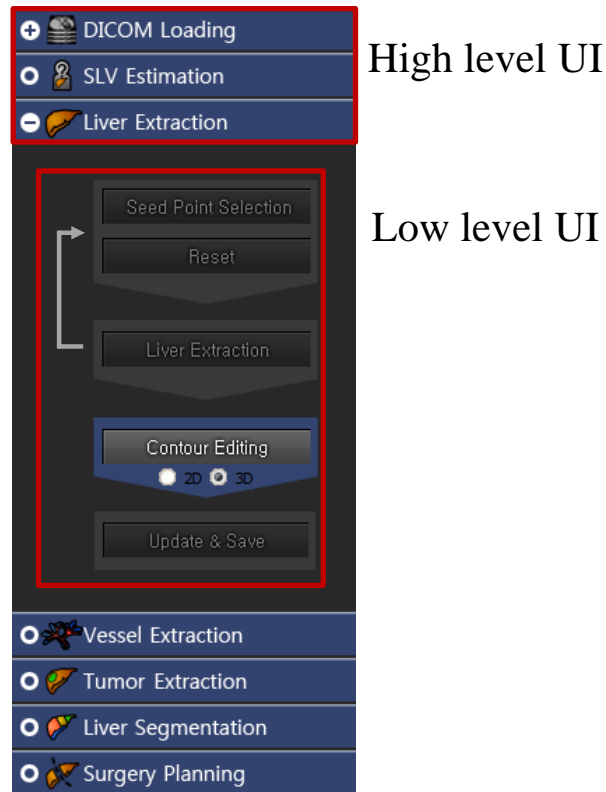


< 1 min

- **Update & save** of the 3D liver

User-Friendly UI Features (1/4)

- A **hierarchical** and **sequential** user interface was designed based on the **use scenario**



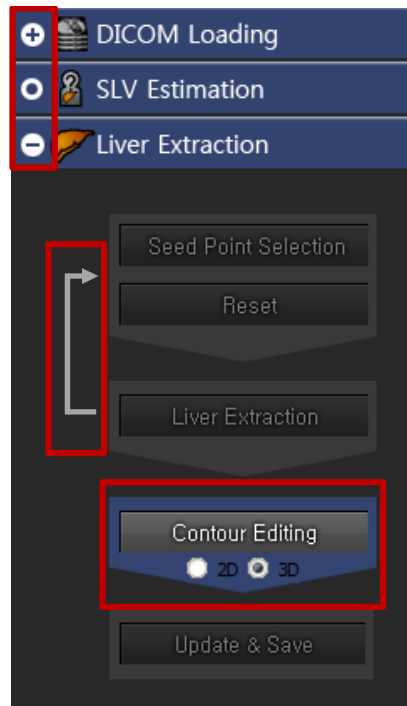
User-Friendly UI Features (2/4)

- Procedure **status indication** and **color coding**
- Iterative execution **arrow**

Procedure status
Indication coding

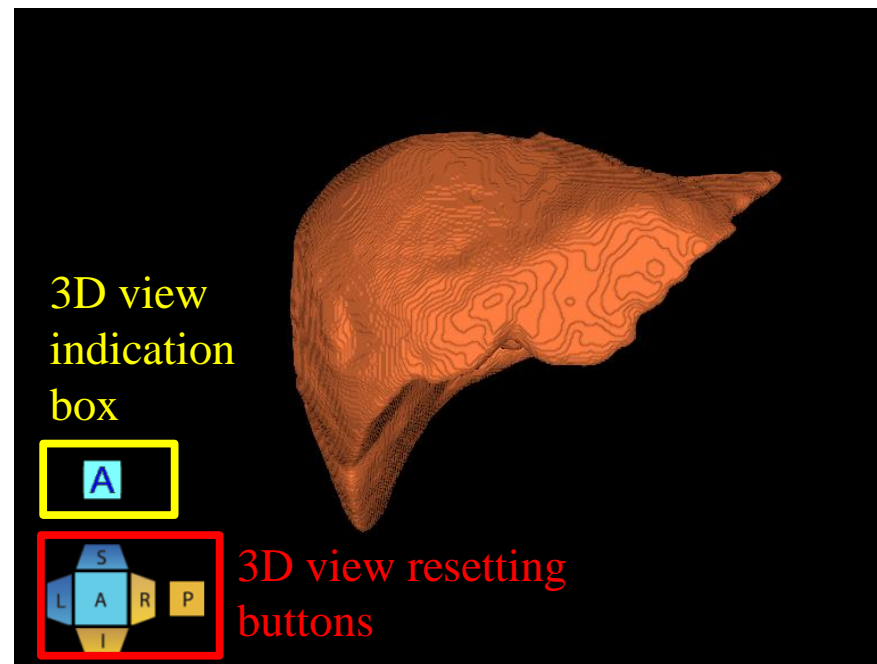
Iterative execution
arrow

Procedure status
color coding



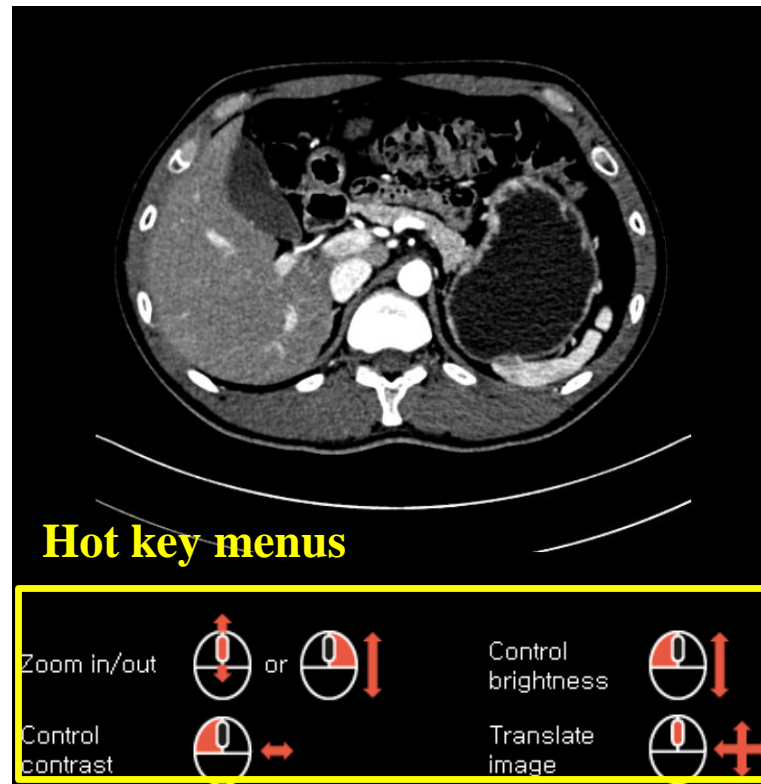
User-Friendly UI Features (3/4)

- 3D view indication and resetting functions for easier 3D object manipulation



User-Friendly UI Features (4/4)

- **Hot key menus** on the 2D screen for easier accomplishment of various tasks such as seed point selection and CT image zooming in/out



Demo: Liver Extraction Module

The screenshot displays the 'Dr. Liver' software interface. The top row contains three CT scan views: an axial view on the left with a vertical scale from 80 to B, a coronal view in the center with a horizontal scale from R to L and a value of 256, and a sagittal view on the right with a horizontal scale from A to P and a value of 256. The bottom-left quadrant shows a larger axial CT scan with a vertical scale from 80 to B. The bottom-right quadrant features a 3D visualization of the liver and its associated vasculature in a reddish-brown color. A directional pad with letters S, A, R, P, L, I is located below the 3D view. The right-hand side of the interface contains a 'Patient information' panel with fields for Name (1549581(KSD)), Gender (M), and Age (34). Below this is an 'Analyst information' panel with Name (YU*HUI CHEOL) and Date (2012. 08. 18). A central menu lists several modules: DICOM Loading, SLV Estimation, Liver Extraction (highlighted), Vessel Extraction, Tumor Extraction, Liver Segmentation, and Surgery Planning. The 'Liver Extraction' module is further detailed with buttons for 'Seed Point Selection', 'Reset', 'Liver Extraction', 'Contour Editing', and 'Update & Save'. At the bottom, there are volume measurement sliders for Liver, Portal Vein, Artery, Hapatic Vein, IVC, and Tumor, each with a 'ml' unit. A 'Distance Measure' button and a 'Transparency' slider are also present. The bottom right corner includes 'Reset' and 'Exit' buttons.

Demo: Liver Surgery Planning – Sphere Mode

The screenshot displays a medical software interface for liver surgery planning. The main window is divided into several panels:

- Top Left:** Axial CT scan of the abdomen with a vertical scale bar labeled 'T' and 'B' and a value of 80.
- Top Middle:** Coronal CT scan of the abdomen with a horizontal scale bar labeled 'R' and 'L' and a value of 256.
- Top Right:** Sagittal CT scan of the spine with a horizontal scale bar labeled 'A' and 'P' and a value of 256.
- Bottom Left:** Axial CT scan with the liver highlighted in green.
- Bottom Right:** 3D visualization of the liver and its vascular system (portal vein, hepatic veins, and arteries) in various colors (red, green, blue, yellow, purple).

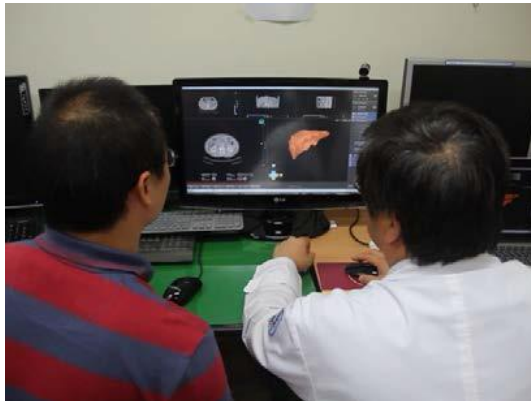
On the right side, there is a sidebar with the following sections:

- Patient information:** Name: 1549581(KSD), Gender: M, Age: 34.
- Analyst information:** Name: YU*HUI CHEOL, Date: 2012. 10. 19.
- Function List:** A list of tools including DICOM trans. (PACS), DICOM Loading, Liver Extraction, Vessel Extraction, Tumor Extraction, Liver Segmentation, and Surgery Planning (which is currently selected).
- Mode Selection:** Radio buttons for Plane, Segment, and Sphere (which is selected).
- Buttons:** Load the Liver, Liver Resection (highlighted), and Update & Save.
- Bottom Right:** Reset and Exit buttons.

At the bottom of the interface, there is a row of checkboxes for volume measurements: Liver Vol ml, Portal Vein Vol ml, Artery Vol ml, Hepatic Vein Vol ml, IVC Vol ml, and Tumor Vol ml. A transparency slider is also present.

Usability Testing

- Participants
 - 3 medical doctors at Chonbuk National University Medical School
 - Age: 30 ~ 50 years
- Patient dataset
 - One dataset of abdominal CT images provided by Chonbuk National University Medical School, South Korea
 - Resolution: 512×512
 - Thickness: 1 mm



Test Design

1. Pre-Test Session (1 h)

1. Informed consent
2. Introduction of usability testing
3. Training of Dr. Liver

2. Test Session (1.5 h)

- Liver extraction
- Vessel extraction
 - Portal vein
 - Hepatic artery
 - Hepatic vein
 - IVC
- Tumor extraction
- Liver segmentation
 - Plane
 - Sphere
- Liver surgery planning
 - Plane
 - Segment
 - Sphere

3. Post-Test Session (10 min)

Debriefing

Measure/Instrument Matrix (selected)

Measures		Liver Extraction	Vessel Extraction	Surgery Planning	Instrument/Scale
Performance	Accuracy (Similarity index, False positive error, and false negative error)	<input type="radio"/>			Comparison to golden standard
	Completion Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Programming
	Number of mouse clicks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Programming
	Number of keystrokes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Programming
Preference	Usefulness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Questionnaire with 7-point Likert Scales
	Ease of Use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	Learnability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	Informativeness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	Clarity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	Tolerance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	Satisfaction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Assessment Questions: Liver Extraction (illustrated)

Questions	Very Poor	Poor	Slightly Poor	Fair	Slightly Good	Good	Very Good
How useful is it for extracting the liver from DICOM images?	①	②	③	④	⑤	⑥	⑦
How easy is it to use?	①	②	③	④	⑤	⑥	⑦
How easy is it to learn the steps of liver extraction?	①	②	③	④	⑤	⑥	⑦
How adequate is the information provided?	①	②	③	④	⑤	⑥	⑦
How clear are the step names?	①	②	③	④	⑤	⑥	⑦
How adequate is the tolerance to allow you make mistakes?	①	②	③	④	⑤	⑥	⑦

Quantitative Assessment Results (selected)

Measures		Liver Extraction	Vessel Extraction	Surgery Planning
Accuracy	SI (%)	97.0 (0.3) 😊	–	–
	FPE (%)	2.0 (0.2) 😊	–	–
	FNE (%)	2.3 (0.4) 😊	–	–
Time (min)	Interaction	1.8 (0.5) 😊	0.6 (0.1) 😊	1.0 (0.2) 😊
	Auto processing	1.3 (0.2) 😊	1.6 (0.3) 😊	1.2 (0.4) 😊
Number of mouse clicks	Before editing	30 (8) 😊	20 (5) 😊	10 (7) 😊
	Editing	56 (10) 😞	0 (0) 😊	4 (2) 😊
Number of keystrokes	Before editing	0 (0) 😊	6 (4) 😊	9 (3) 😊
	Editing	17 (10) 😞	0 (0) 😊	3 (2) 😊

Qualitative Assessment Results - Overall

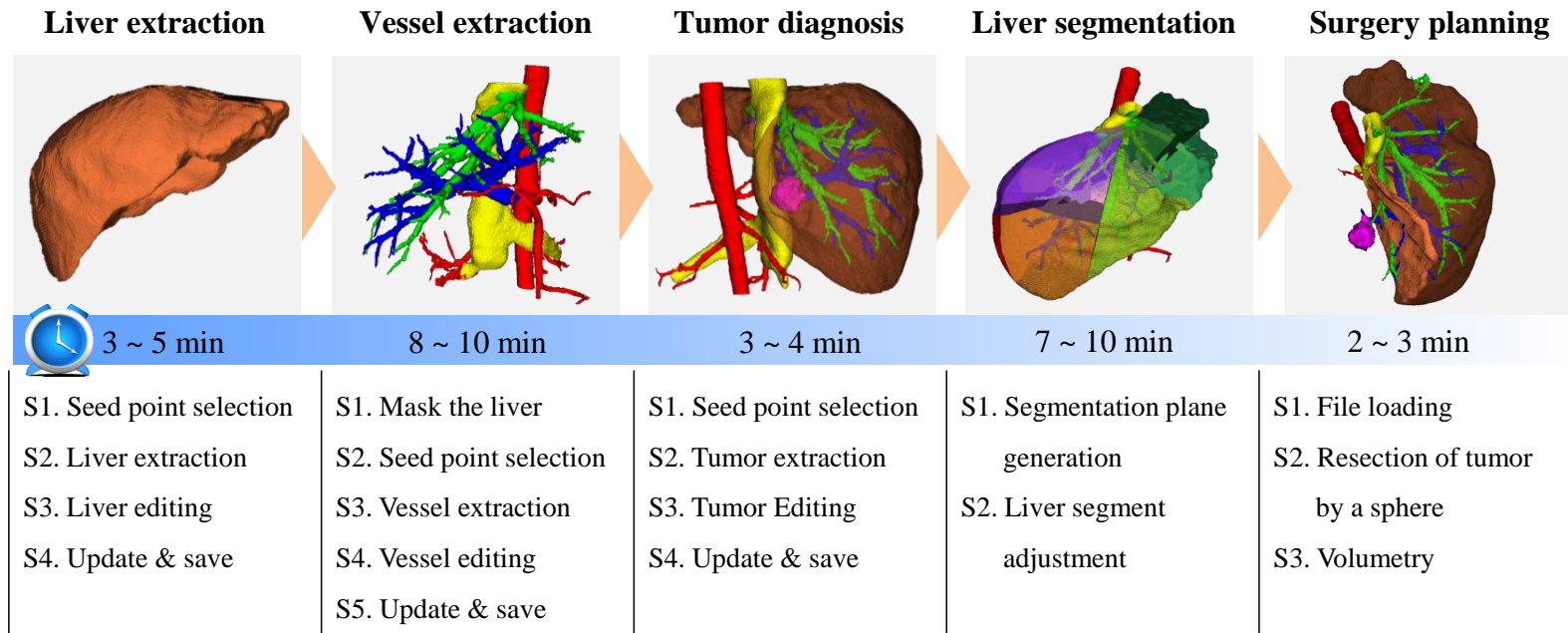
Module		Average	S.D.
Liver extraction		6.7	0.6
Vessel extraction	Portal vein	6.8	0.4
	Hepatic artery	5.2	0.8
	Hepatic vein	6.7	0.5
	IVC	7.0	0.0
Tumor extraction		7.0	0.0
Liver segmentation	Plane	6.7	0.6
	Sphere	6.5	0.5
Liver surgery planning	Plane	6.1	1.1
	Segment	7.0	0.2
	Sphere	7.0	0.2

Low score:
Incomplete
extraction of HA

Large variation:
high scores
provided by
young doctors, but
a low score by a
senior doctor

Discussion (1/3)

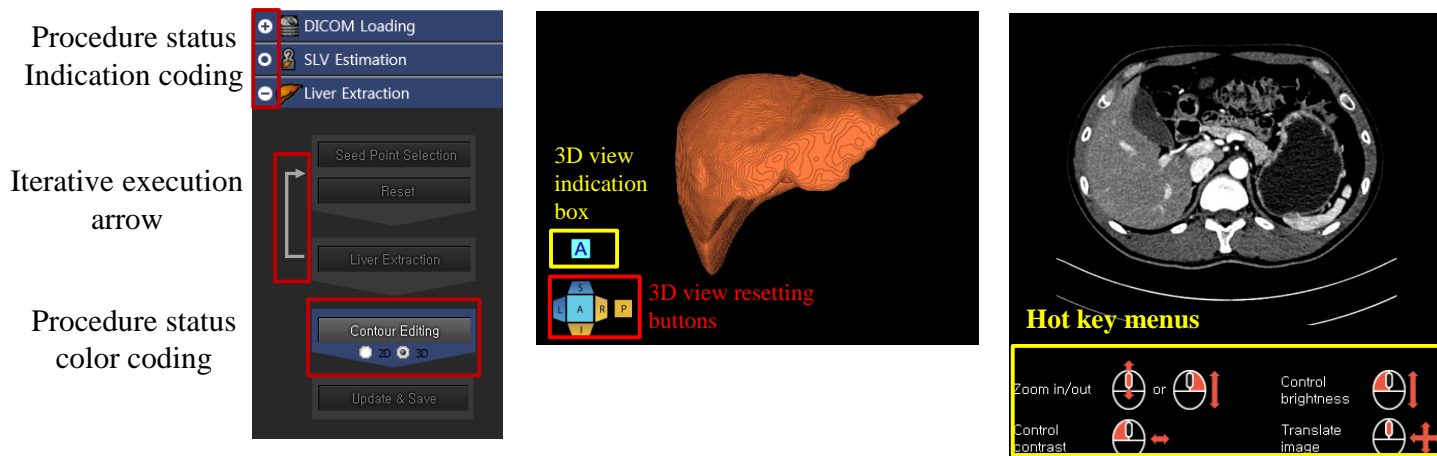
- Use scenario development based on interviews with surgeons, benchmarking of commercialized systems, literature survey, and questionnaires
 - User-centered
 - Clinically practical



Entire processing time: 20 ~ 30 min

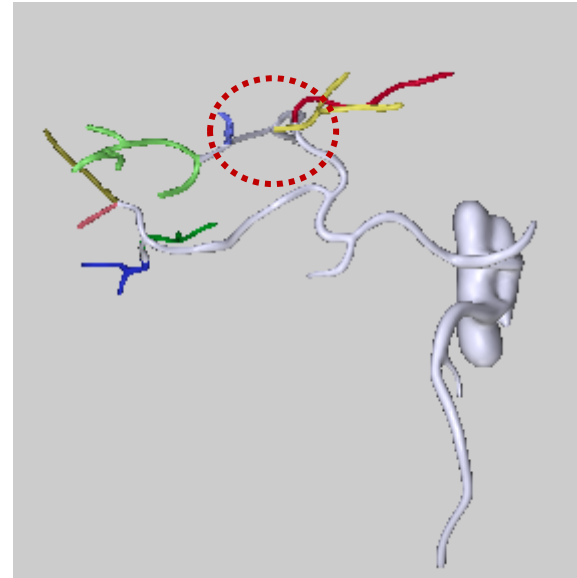
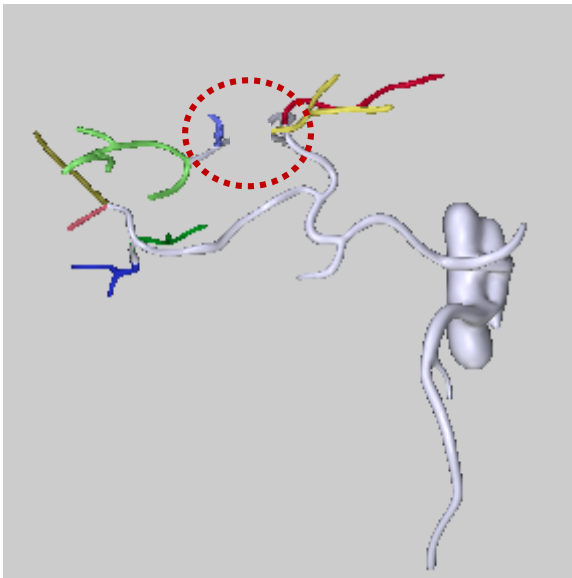
Discussion (2/3)

- User-friendly UI design
 - Procedure-based and intuitive
 - Procedure status indication and color coding
 - 3D view indication box and resetting buttons for easier 3D object manipulation
 - Hot key menus on the screen to decrease cognitive workload



Discussion (3/3)

- Usability testing
 - Improvement needed: Connection function for discontinued extraction of HA branches
 - Usability testing at multiple centers



Liver Anatomy Workshop @ POSTECH



FEATURES

1 Clinical Decision Support for Safe and Rational Surgery

- Semi-automated extraction of the liver, vessels (PV, HV, HA, and IVC), and lesions
- Real-time, interactive boundary editing
- Customized liver segmentation based on PV and HV structures
- Volumetry of the liver, vessels, lesions, and liver segments
- Optimal surgery planning support based on risk analysis and resection strategies

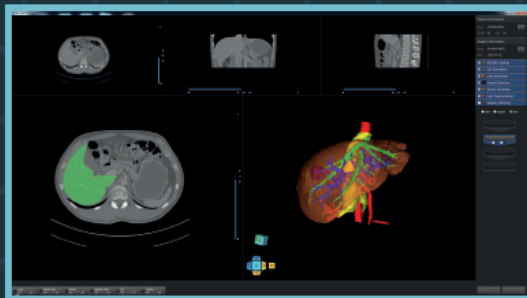
2 User-Friendly Interface

- Procedure-based and hierarchical workflow
- Easy to learn and use
- Multi-modal (text, graphic, and voice) guidance

3 Time Efficiency in Surgery Planning

- Efficient workflows (20 min from liver extraction to surgery planning)

System Overview



System Requirement

PC	OS	Windows 7 64 bit or higher
	HDD	2 GB or larger
	CPU	i5 3.1 GHz or higher
	RAM	8 GB or larger
	VGA	GeForce GT 630 or higher
Monitor	Resolution	1920 × 1080 or higher

Retailer Information

Distributor: Humanopia Co., Ltd.

Address: 323 Main Building, Pohang Techno Park
394 Jigok-ro, Nam-gu
Pohang, Gyungbuk, 790-834, South Korea

Tel: +82-54-223-2268~9

E-mail: eurinam@hotmail.com

Webpage: www.humanopia.co.kr

Dr. Liver is a virtual liver surgery planning system to help surgeons plan liver surgery with high accuracy and ease of use in a reasonable time.

Dr. Liver pursues excellence in functionality for clinical decision support for safe and rational surgery and user-friendly interface.

The User-Friendly Virtual Liver Surgery Planning System

1 SLV Estimation

The standard liver volume of a patient can be estimated based on the height and weight of the patient using three formulas (Yu et al., 2004; Urata et al., 1995; and Heinemann et al., 1999)

SLV Estimation

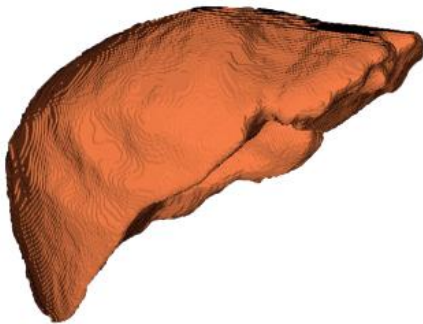
Height cm

Weight kg

Yu et al.	1546.8 ml
Urata et al.	1307.6 ml
Heinemann et al.	1637.0 ml

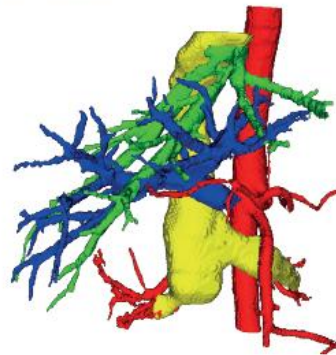
2 Liver Extraction

The liver can be automatically extracted in 2 ~ 4 min using a sophisticated algorithm (termed as hybrid liver extraction method) once multiple seed points are selected on 5 ~ 6 slices by the user.



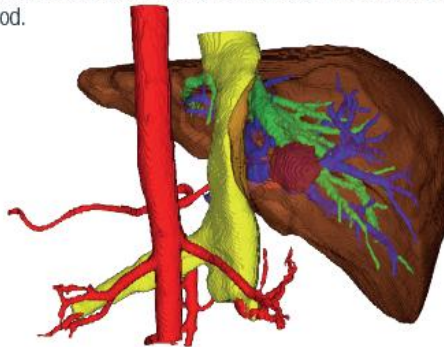
3 Vessel Extraction

The PV, HA, HV, and IVC can be extracted in 2 min each using modified region growing methods, which use multiple seed points, masked CT images, and an optimal threshold interval identified by the K-means clustering method.



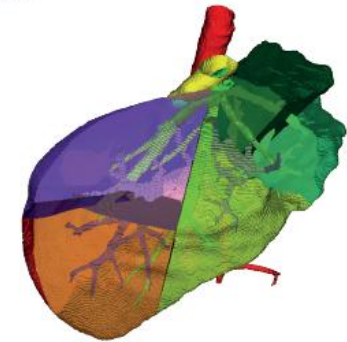
4 Tumor Extraction

The tumor(s) can be extracted in 2 min by a threshold-based level-set method, which uses multiple seed points and an optimal initial threshold interval automatically identified by the K-Means clustering method.



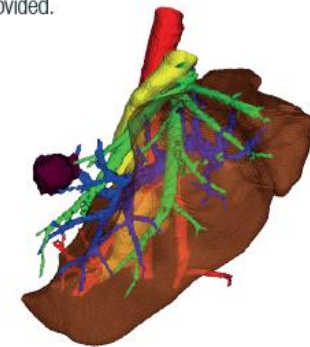
5 Liver Segmentation

The liver can be divided into segments in 1 ~ 3 min per segmentation according to Couinaud's classification method based on the PV and HV structures. Two modes (plane and sphere) are available for segmentation.



6 Liver Surgery Planning

The resected area of the liver can be defined using one of three different modes (plane, segment, and sphere). The volumes of the liver and remnant/graft and the percentage of the remnant liver volume are provided.



Q & A

Thank you for your attention!

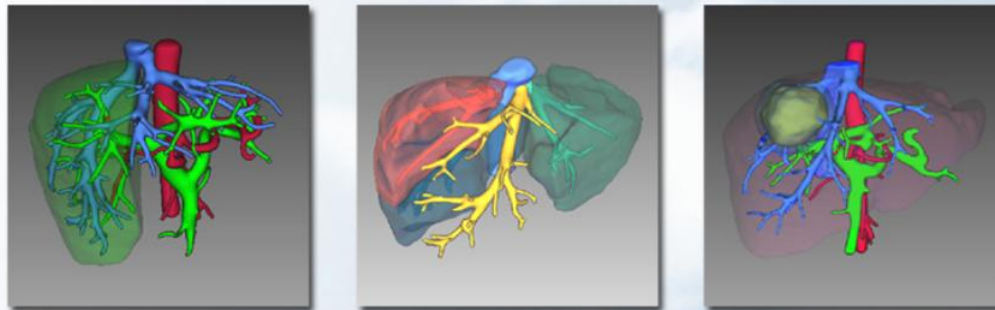


IQQA Liver

- Developed by EDDA, USA

IQQA-Liver is the latest innovation addressing multi-departmental needs in treatment planning for liver surgery, transplantation and interventional procedures. Our system allows you to achieve:

- Automated 3D Analysis
- Volume Measurements
- Virtual Simulation
- 3D Spatial Relationship
- And more



Limitations:

- Expensive and no specifications of the system provided
 - No **usability testing** of the system provided
- ⇒ **Not available** for **evaluation** and close **comparison**