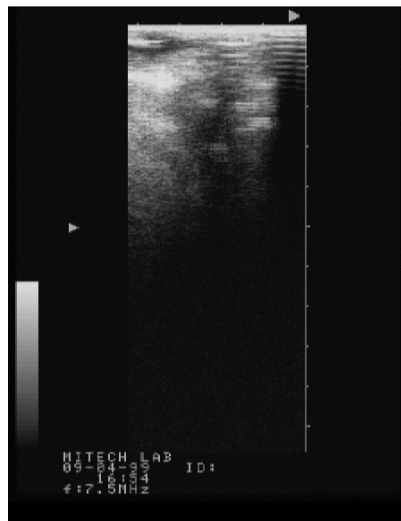


VISUALIZZAZIONE IMMAGINI BIOMEDICALI 3D

Vincenzo Ferrari
vincenzo.ferrari@unipi.it

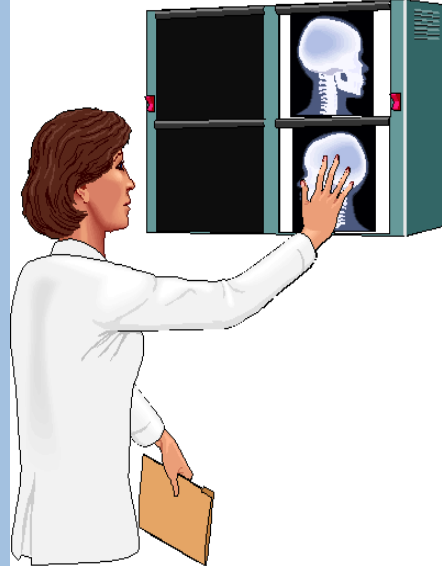
LE IMMAGINE MEDICALI NON SOLO PER FINALITA' DIAGNOSTICHE





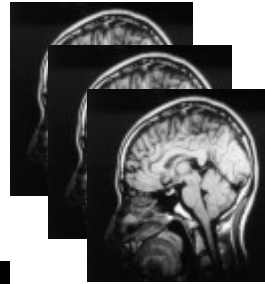
Radiological Images for Surgical Planning

3D 'Mental Reconstruction'
for diagnosis and planning

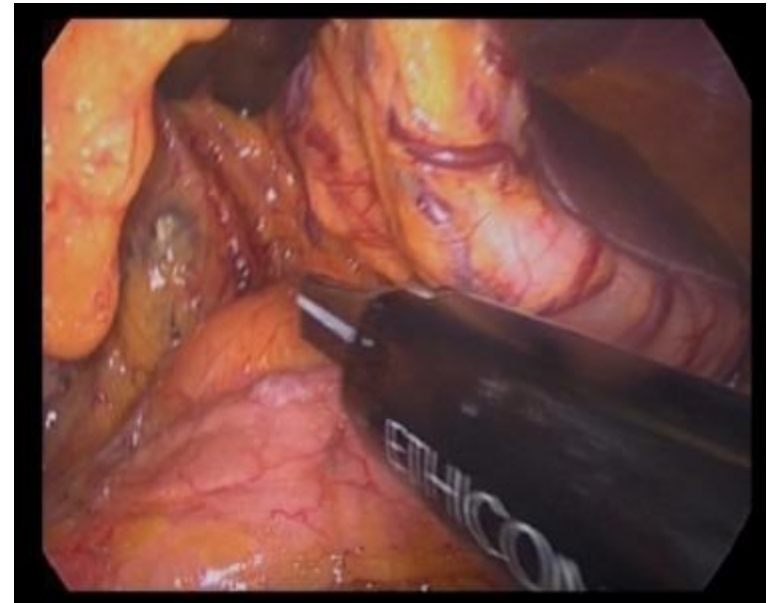


Diagnosis

Image
Acquisition

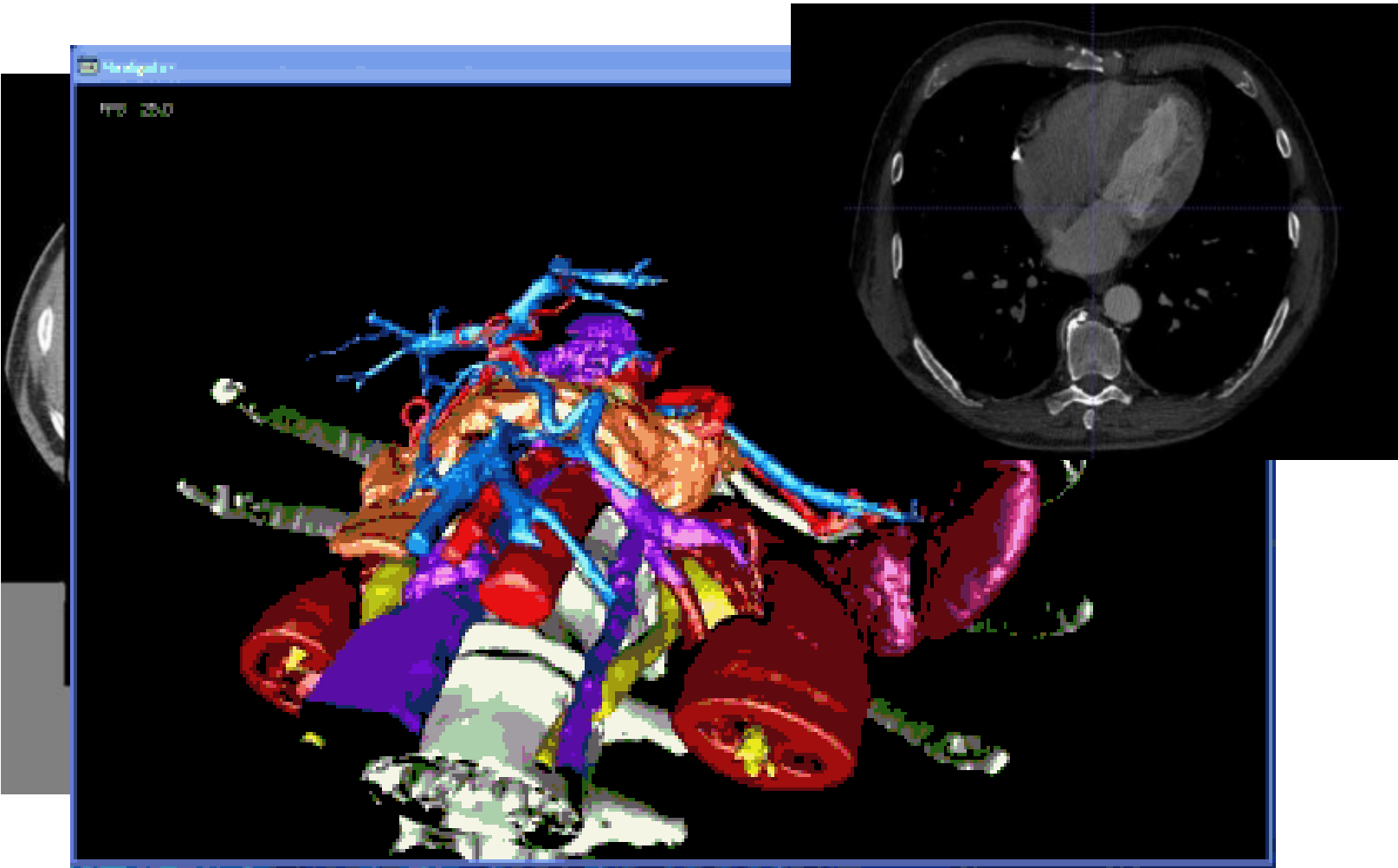


Intervention

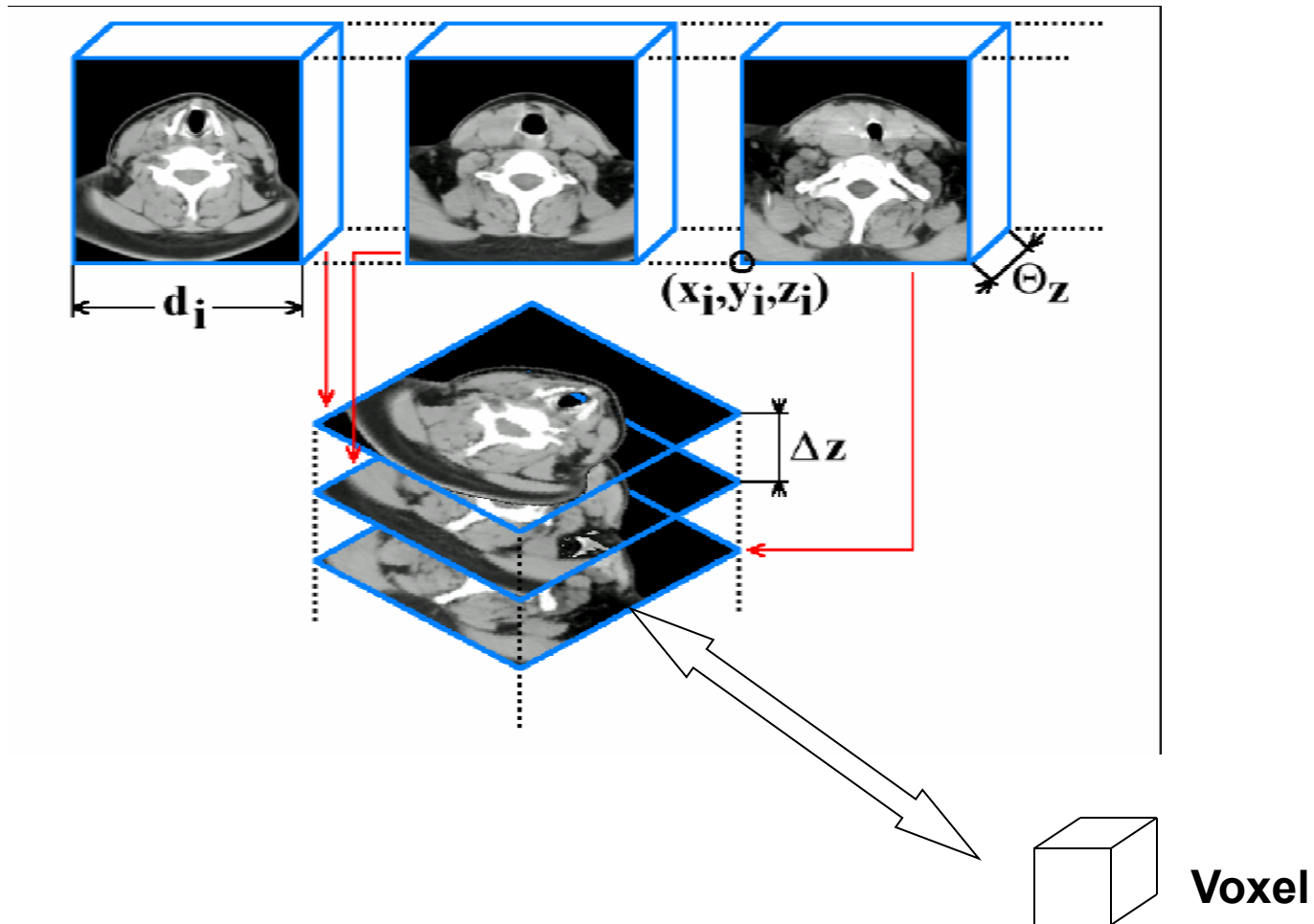


Medical v1

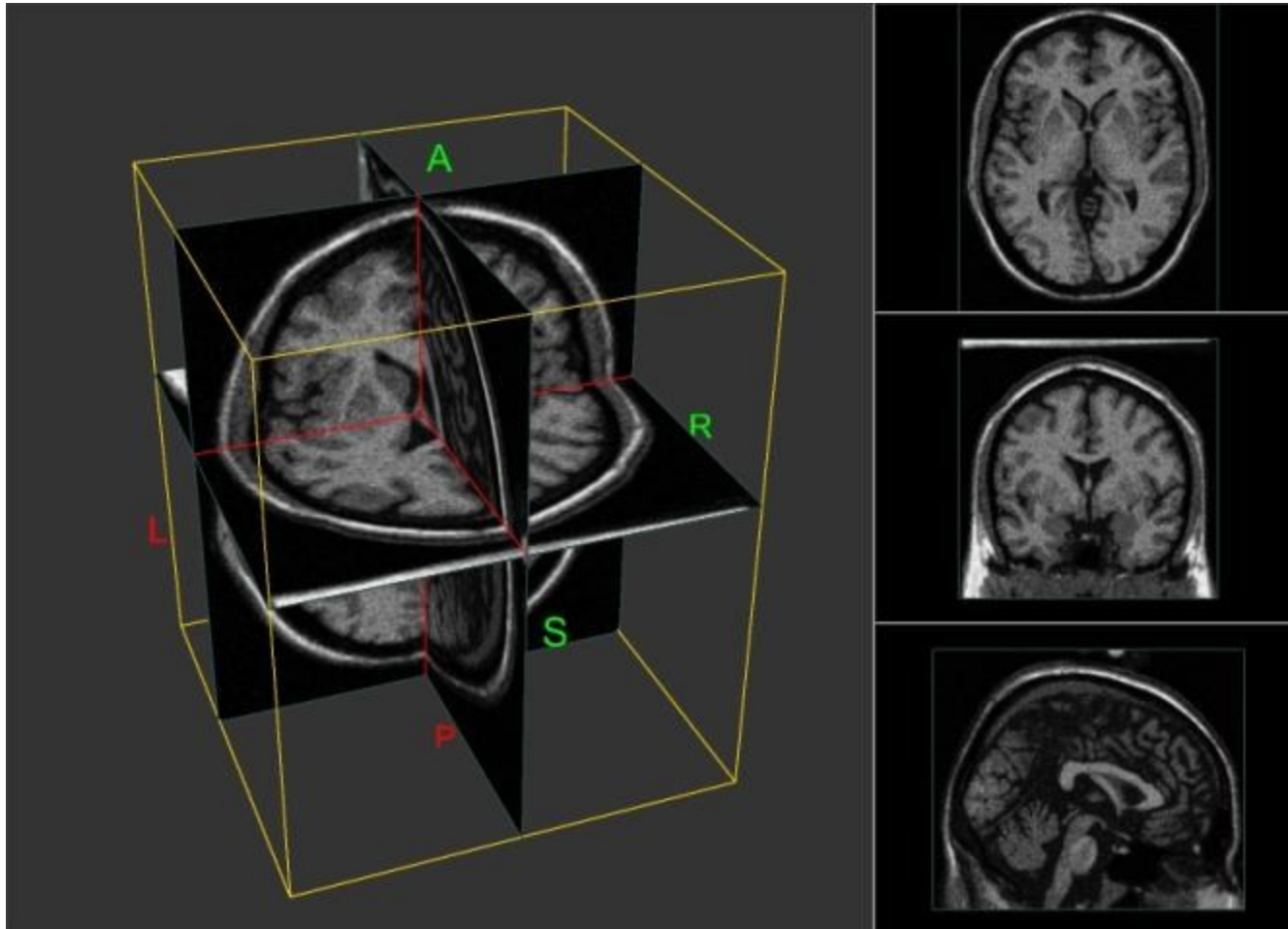
170 25.0



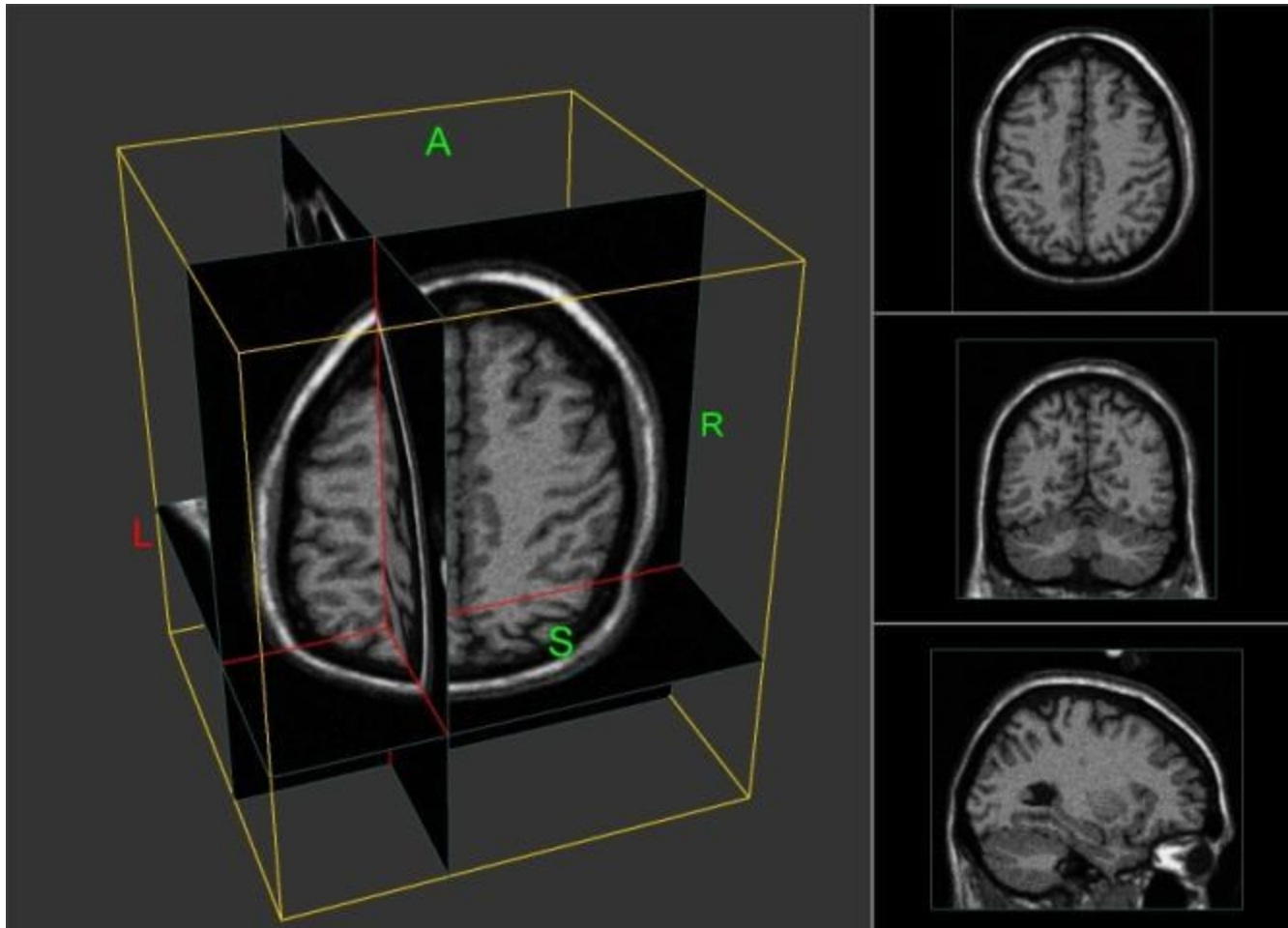
VISUALIZATION OF 3D DATASET



Volume Slicing - Esempio



Volume Slicing - Esempio



ESEMPIO

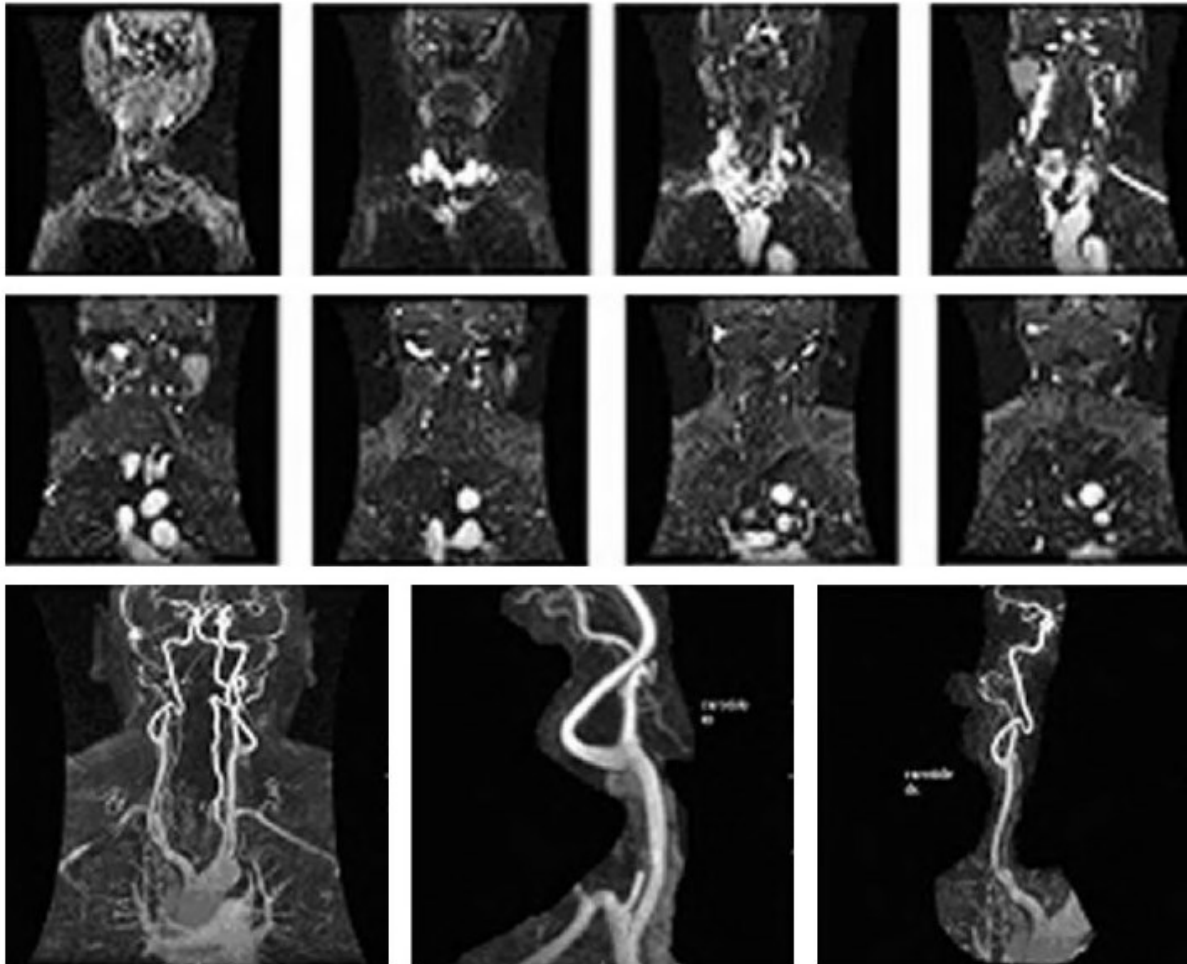
- INVESALIUS http://www.cti.gov.br/invesalius/?page_id=8

Accenni di computer graphics

- Contenuto 3D su schermo 2D (poi estenderemo ad altre tipologie di schermi)

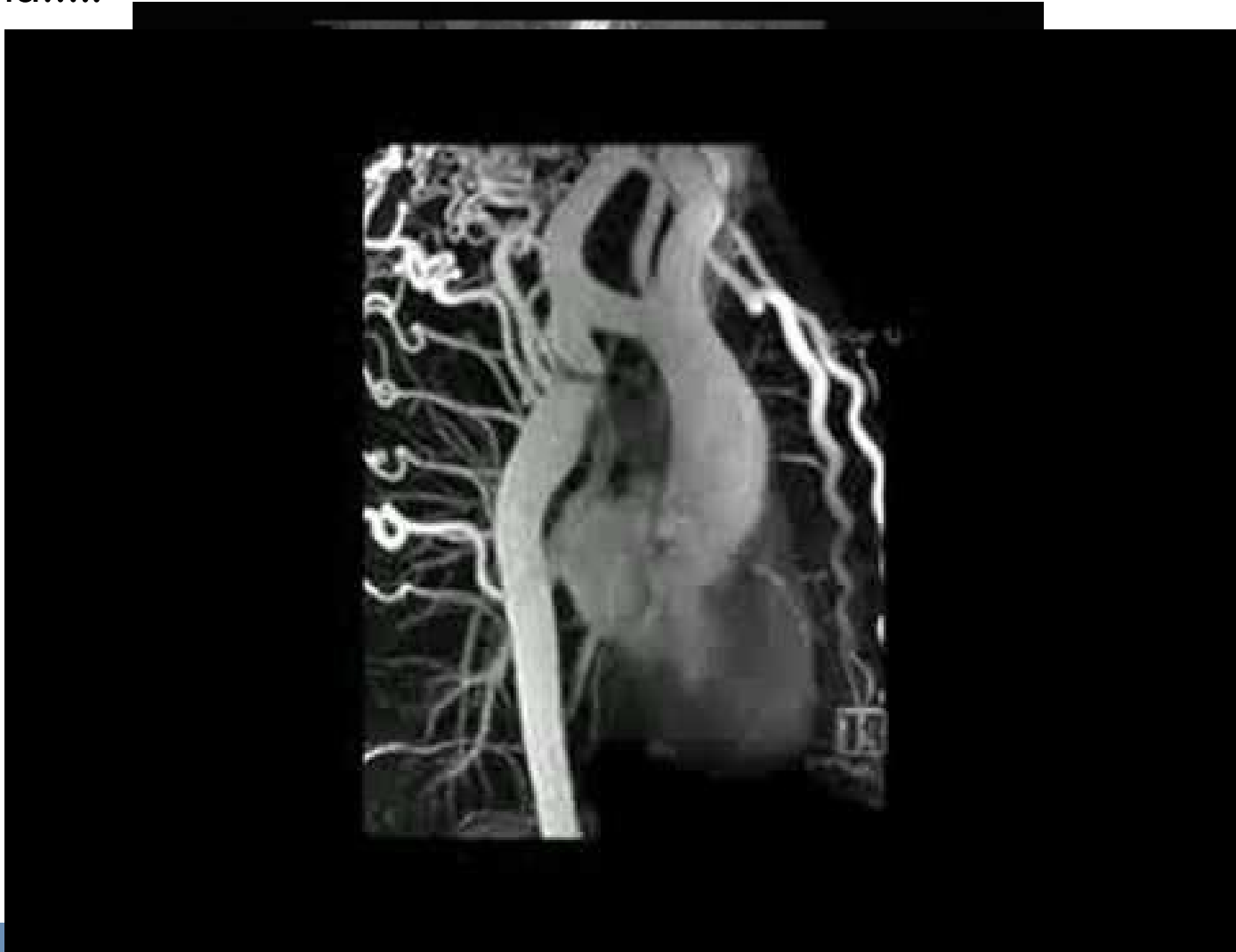
MIP (Maximum Intensity Projection)

Esempio con Invesalius



MIP (Maximum Intensity Projection)

- Non solo proiezioni a massima intensità (MIP) ma anche minima, somma.....



Accenni di computer graphics

- Accenni ottica geometrica (quando e come è possibile approssimare il comportamento dei fotoni con «raggi di luce»); importanza delle interfacce loro significato ottico.
- **Esempio con blender** (<http://www.blender.org/>) :
 - scenario virtuale,
 - camera virtuale,
 - rendering,
 - immagine risultato «renderizzata»,
 - display,
 - spunti per comprendere la terza dimensione,
 - interazione con la scena (parallasse di movimento).

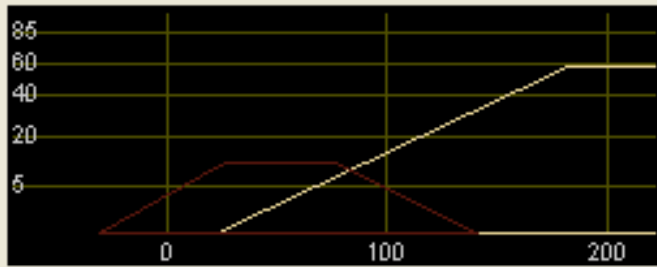
Direct Volume Rendering

Tecnica usata per mostrare una proiezione 2D di un dataset discreto 3D

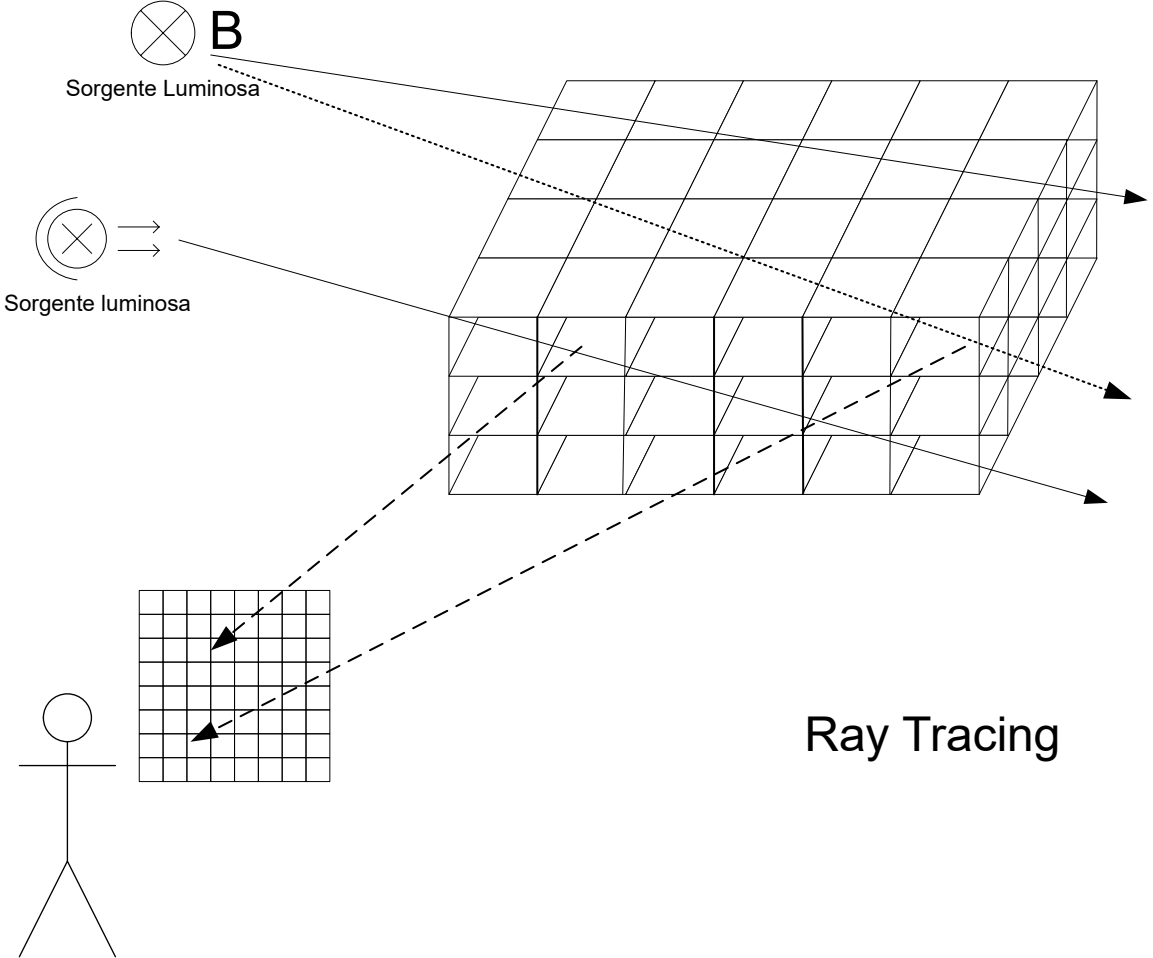


visualization of 3D dataset: Direct Volume Rendering

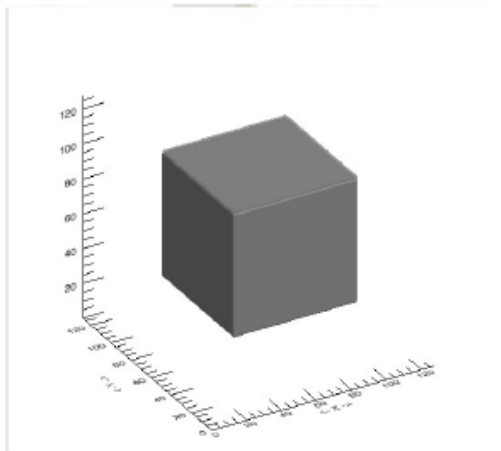
- ❑ No pre-elaboration
- ❑ Slow
- ❑ Noisy



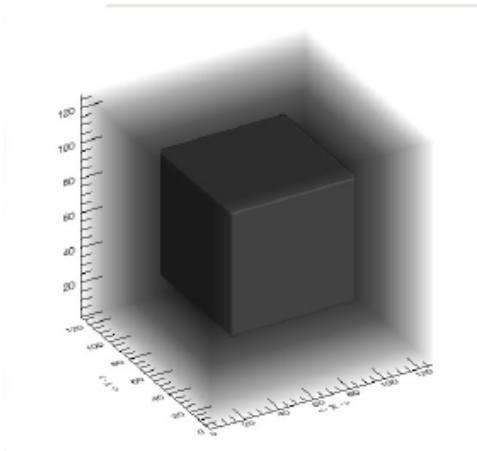
FUUNZIONAMENTO DIRECT VOLUME RENDERING



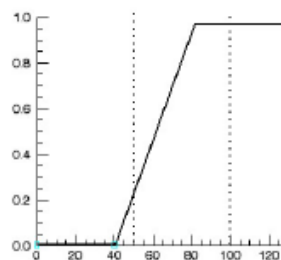
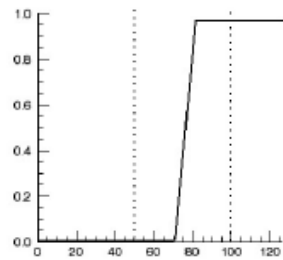
DIRECT VOLUME RENDERING: opacità



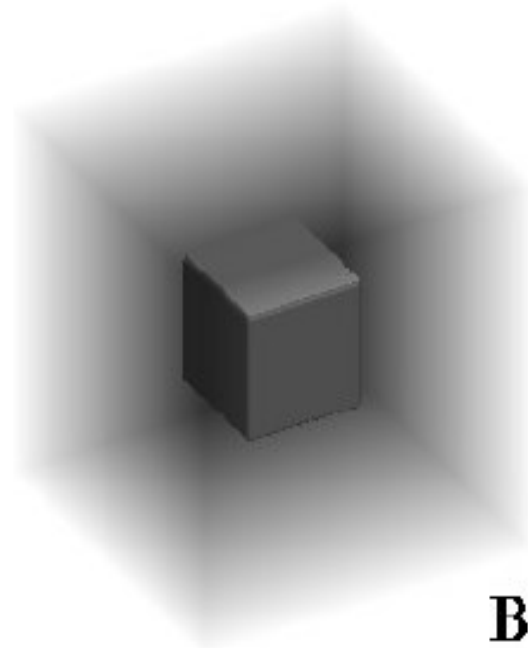
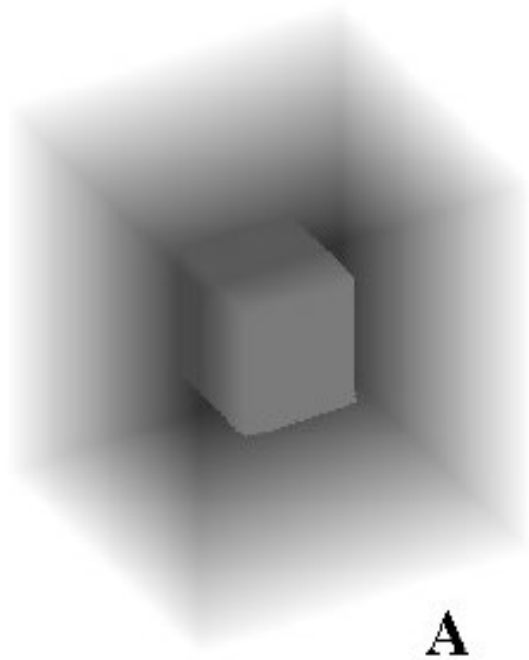
A



B

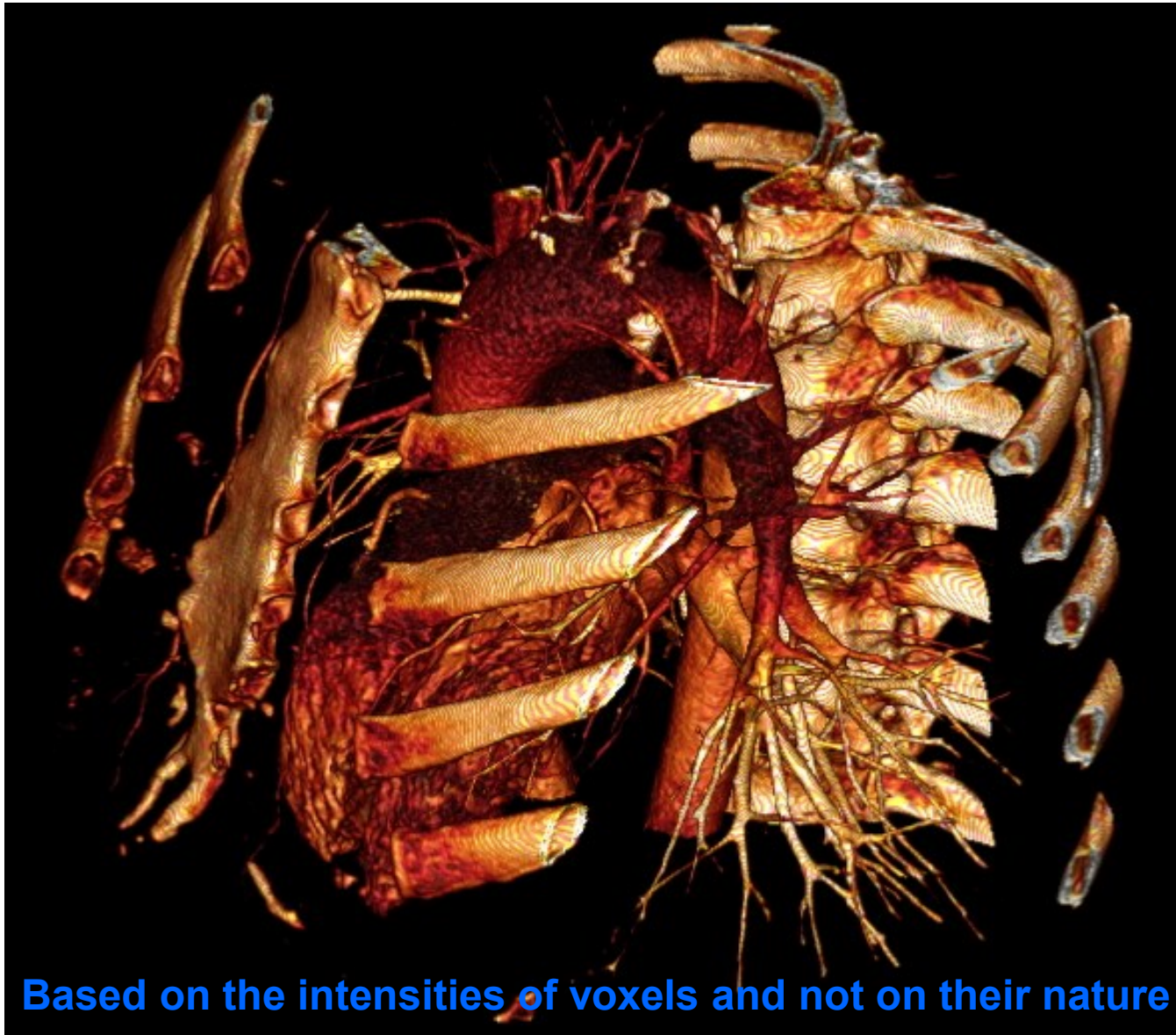


DIRECT VOLUME RENDERING: shading



- Calcolo delle interfacce....

DIRECT VOLUME RENDERING

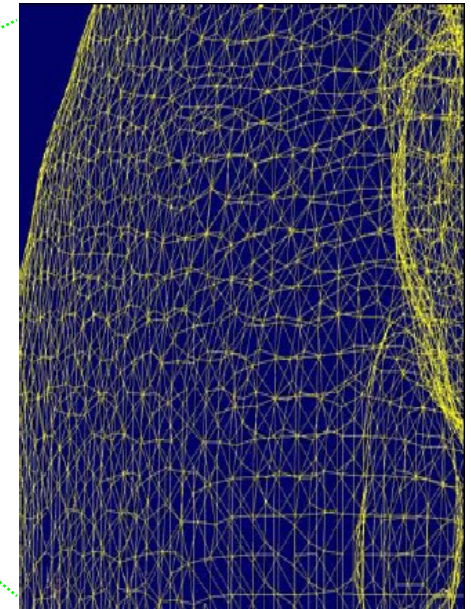


DIRECT VOLUME RENDERING

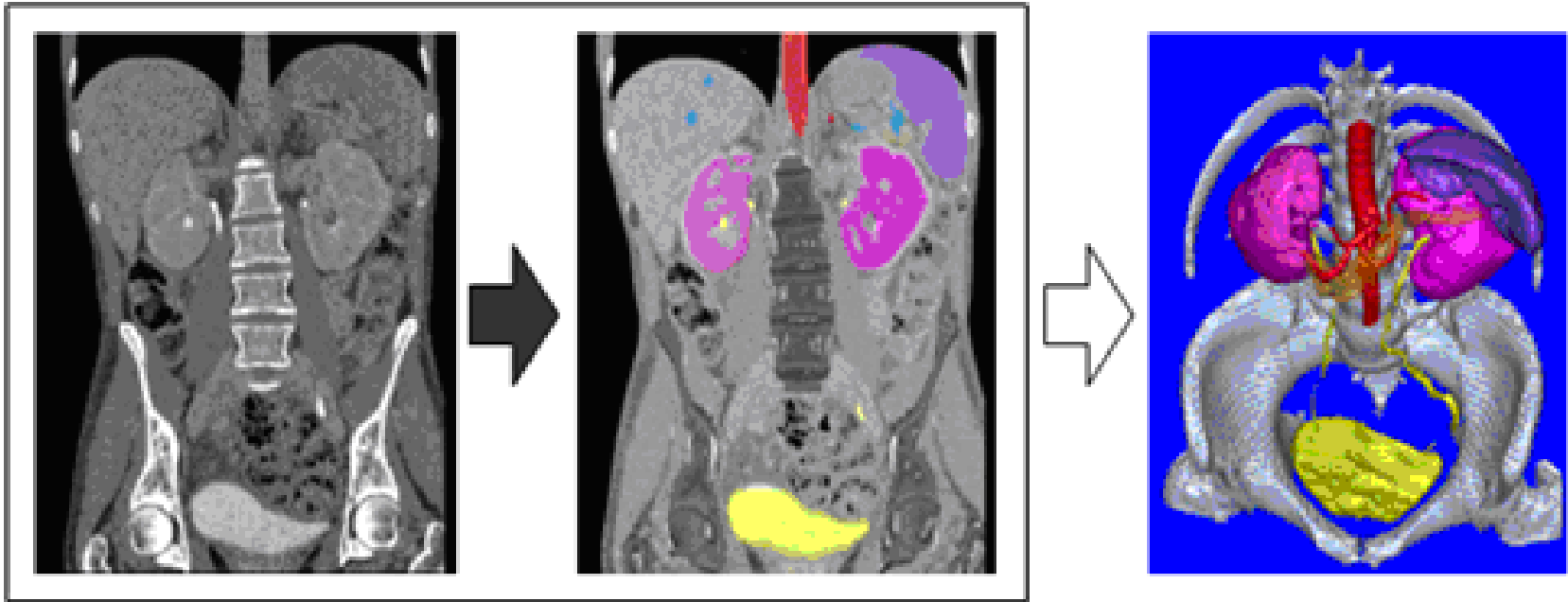
- INVESALIUS http://www.cti.gov.br/invesalius/?page_id=8

Surface Rendering

- Fast
- You can select and change properties for each organ (for example pancreas transparency, see below)



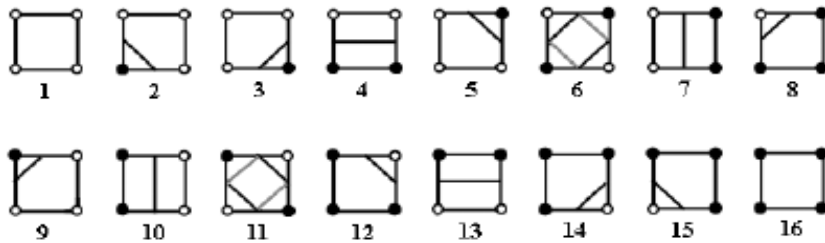
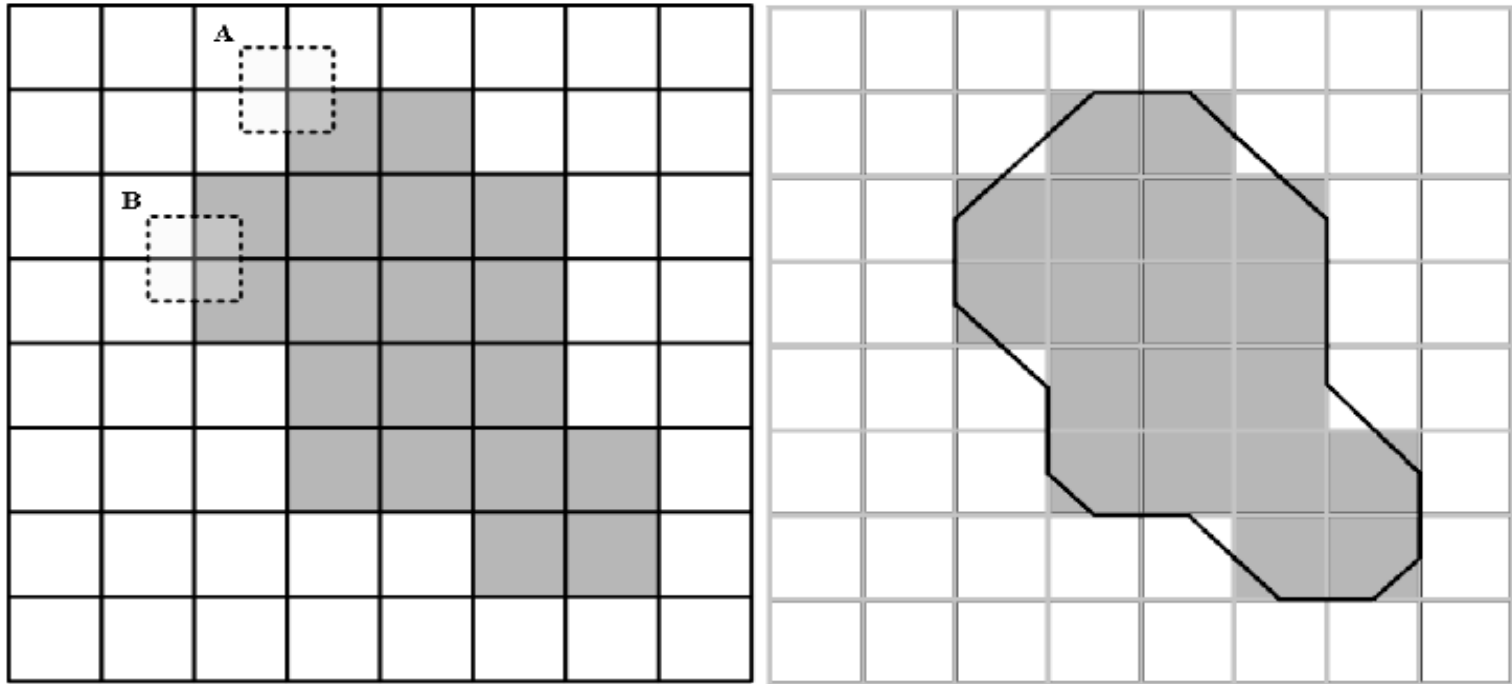
Segmentation



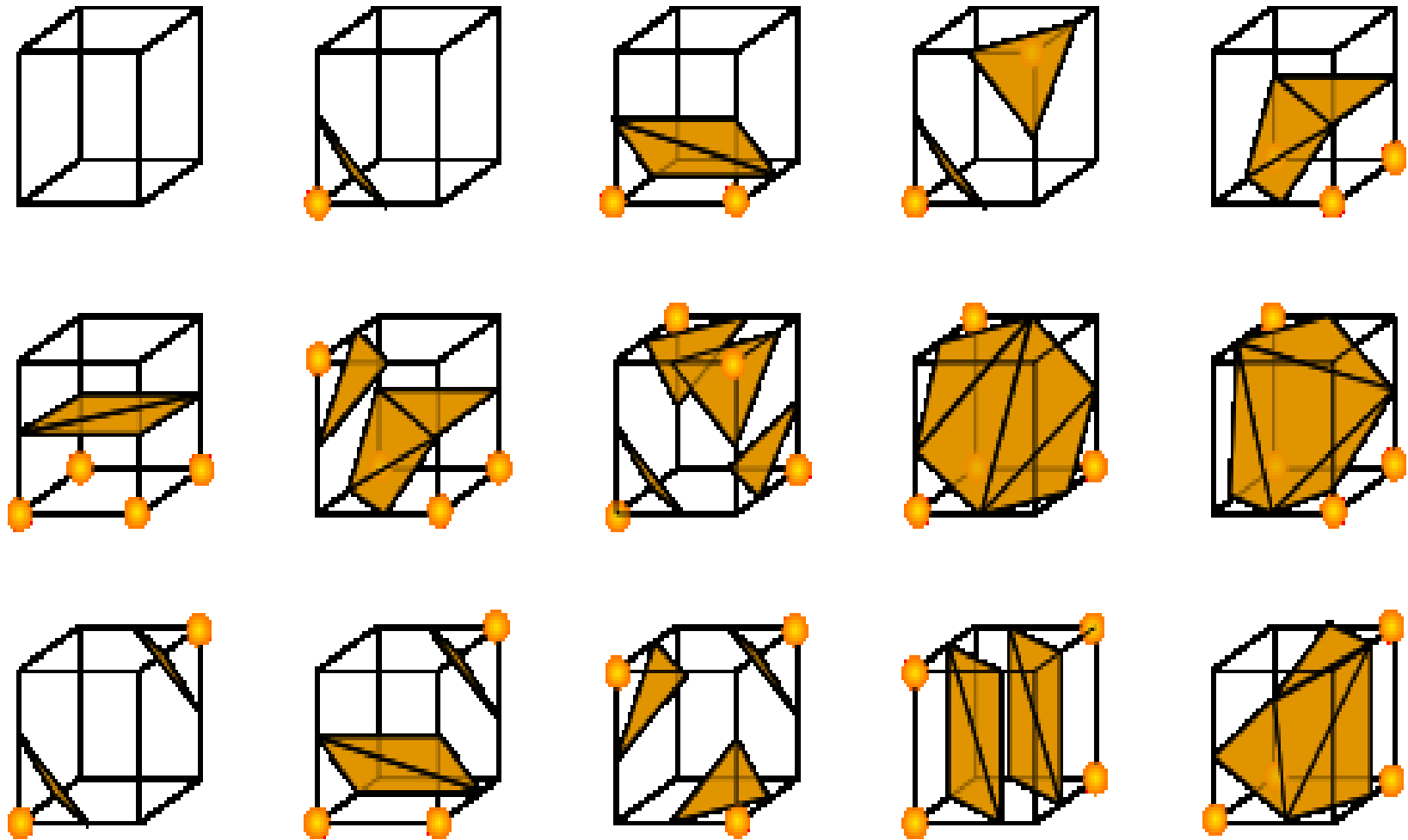
Segmentation process discriminates the anatomical structures and assigns each voxel of the image to the relative virtual object (Virtual Organ).

Knowing voxel dimensions it is consequently possible to describe geometrically (morphologically) each segmented region.

Marching Cube



Marching Cube

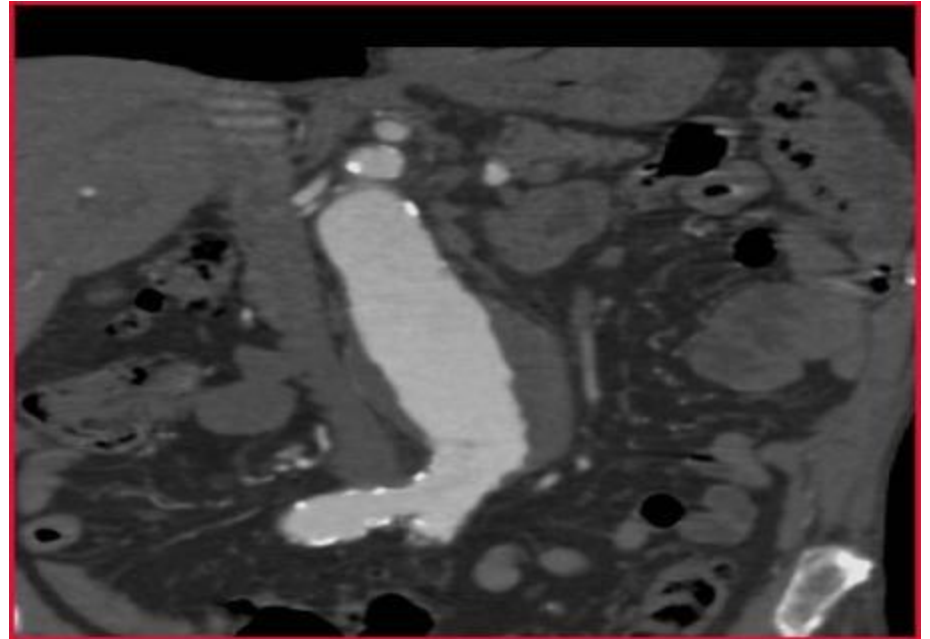
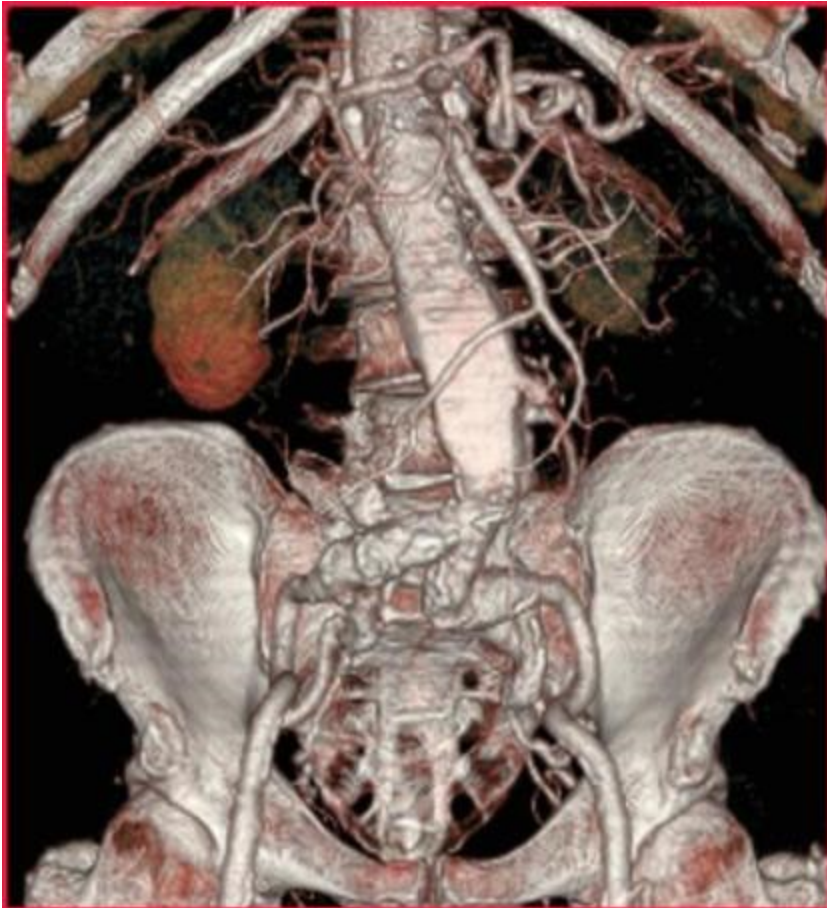


Accenni di computer graphics

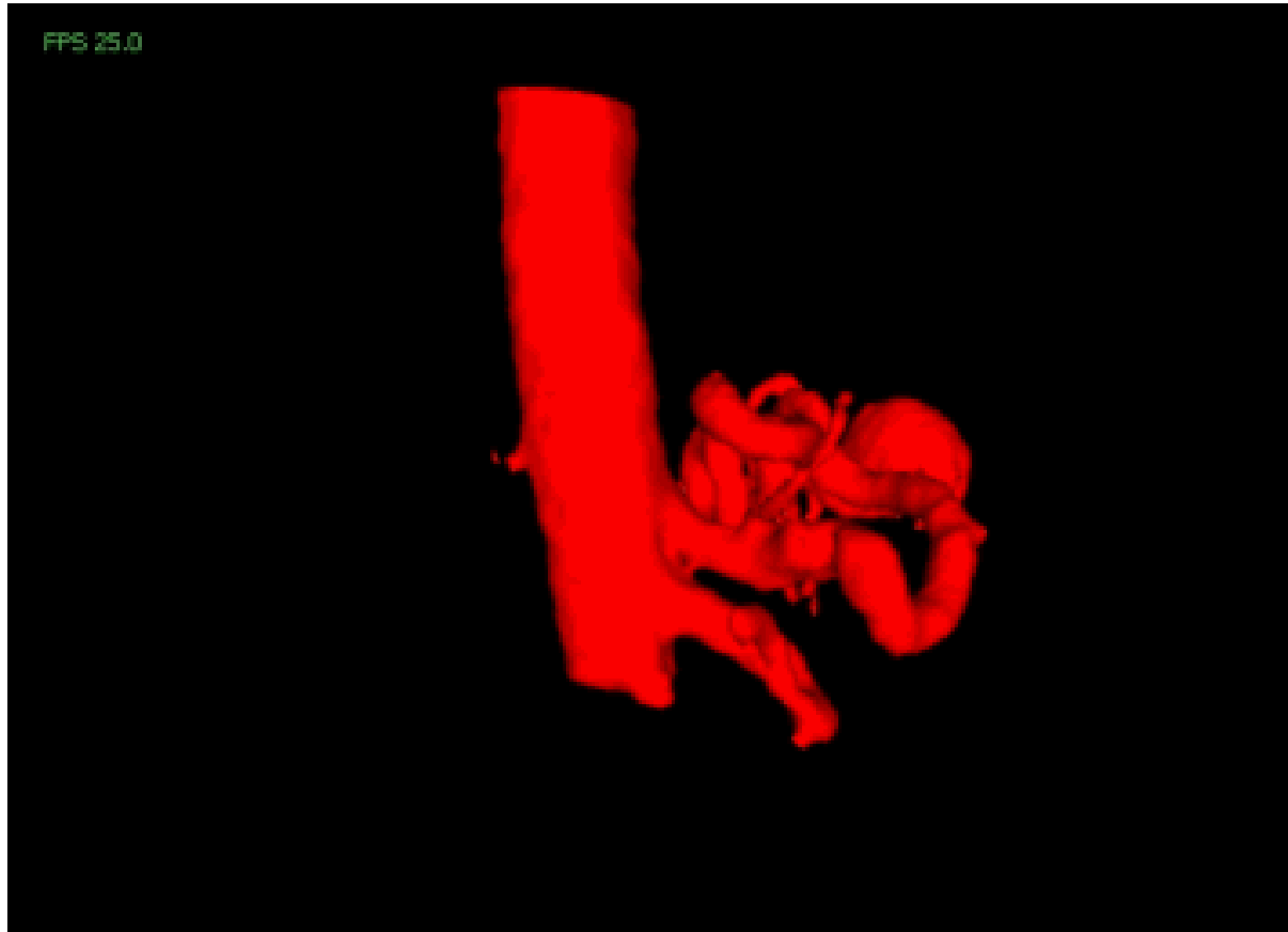
- Esempio con blender (<http://www.blender.org/>) :
- Rappresentazioni a poligoni
 - Struttura file stl e wrl; «giocare» con le coordinate dei vertici.

Segmentation or Direct Volume Rendering?

Direct volume rendering (left) of an abdominal aneurysm (CT, right)

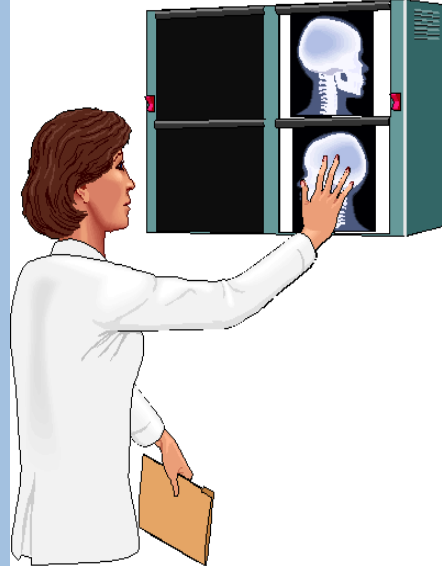


visualization of 3D dataset: Surface or Volume rendering?



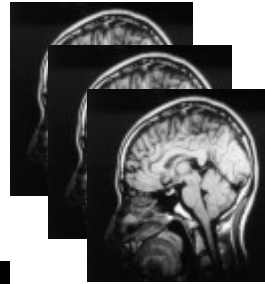
Radiological Images for Surgical Planning

3D 'Mental Reconstruction'
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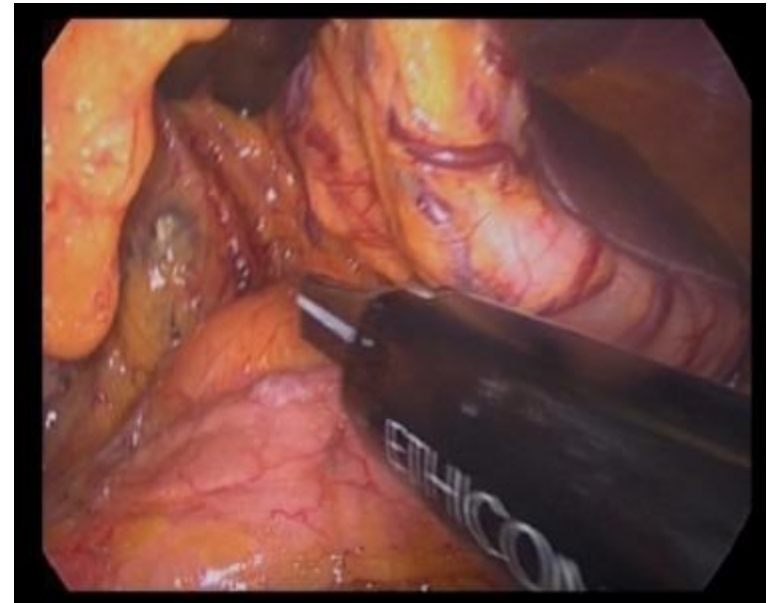


Diagnosis

Image
Acquisition



Intervention



SL

A

RS

LI

X

IR



SL

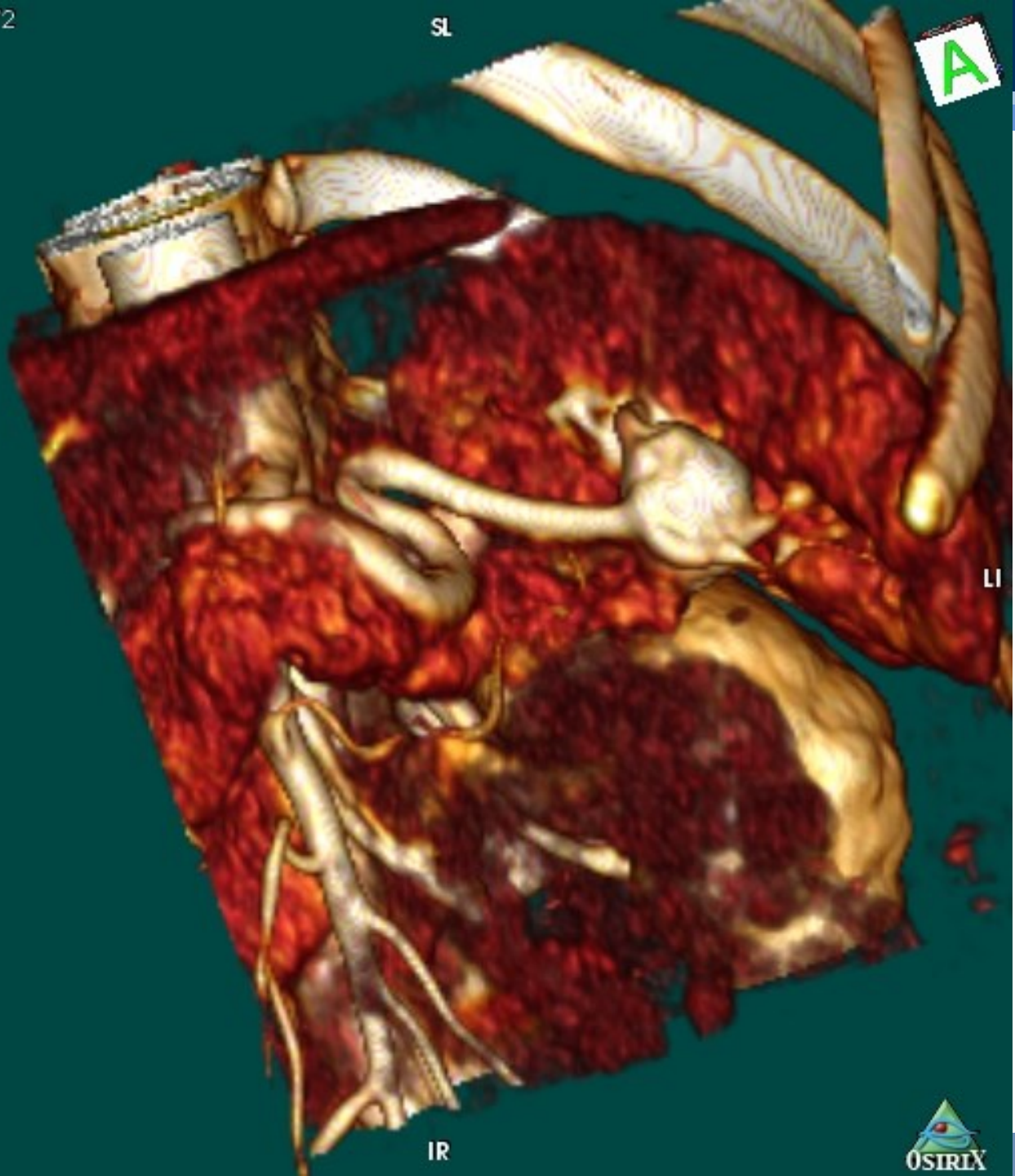
A

RS

LI

X

IR



WL: 90 WW: 72

SPL

S
A

RS

LI

X

IAR



SPL



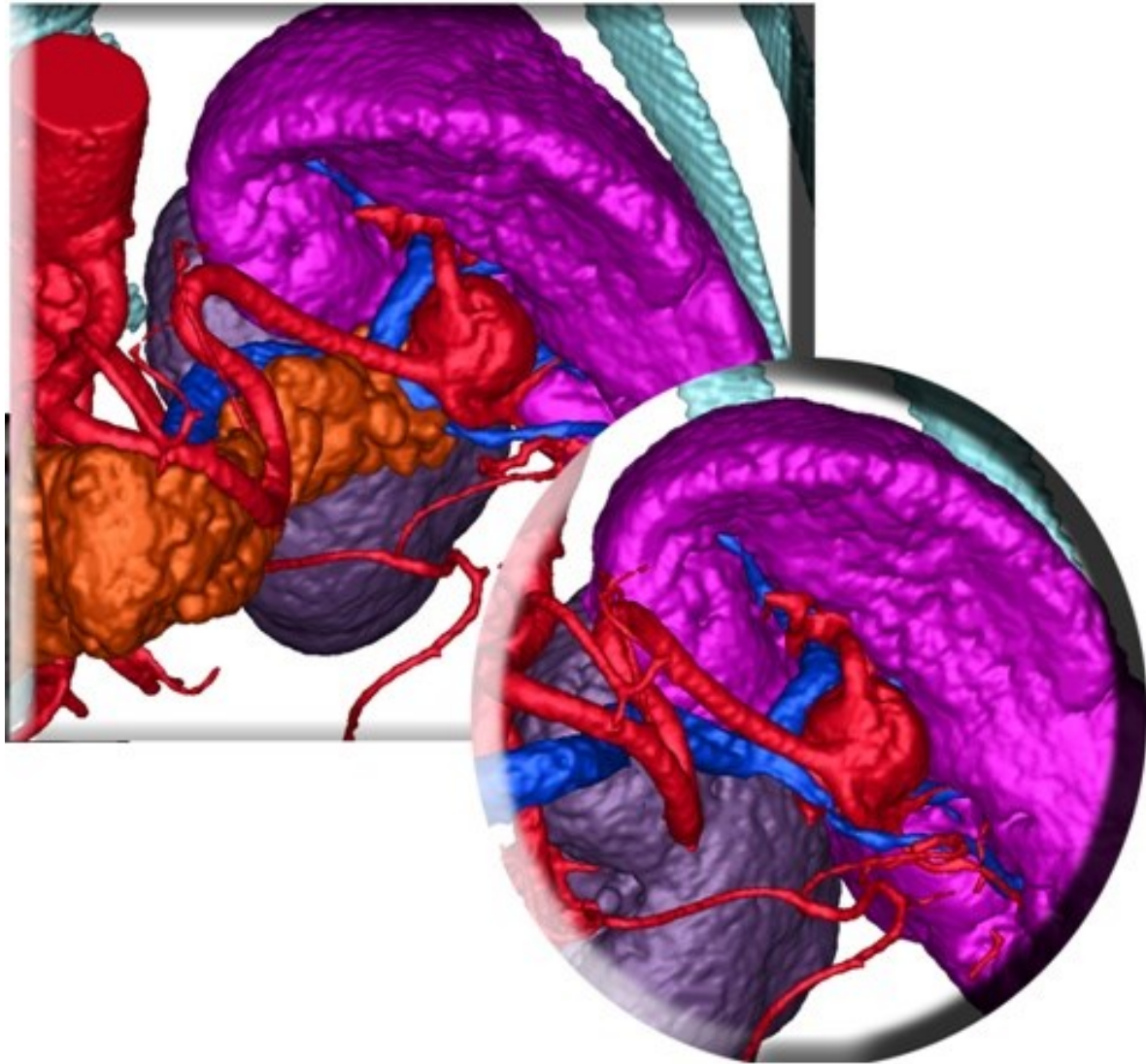
RPS

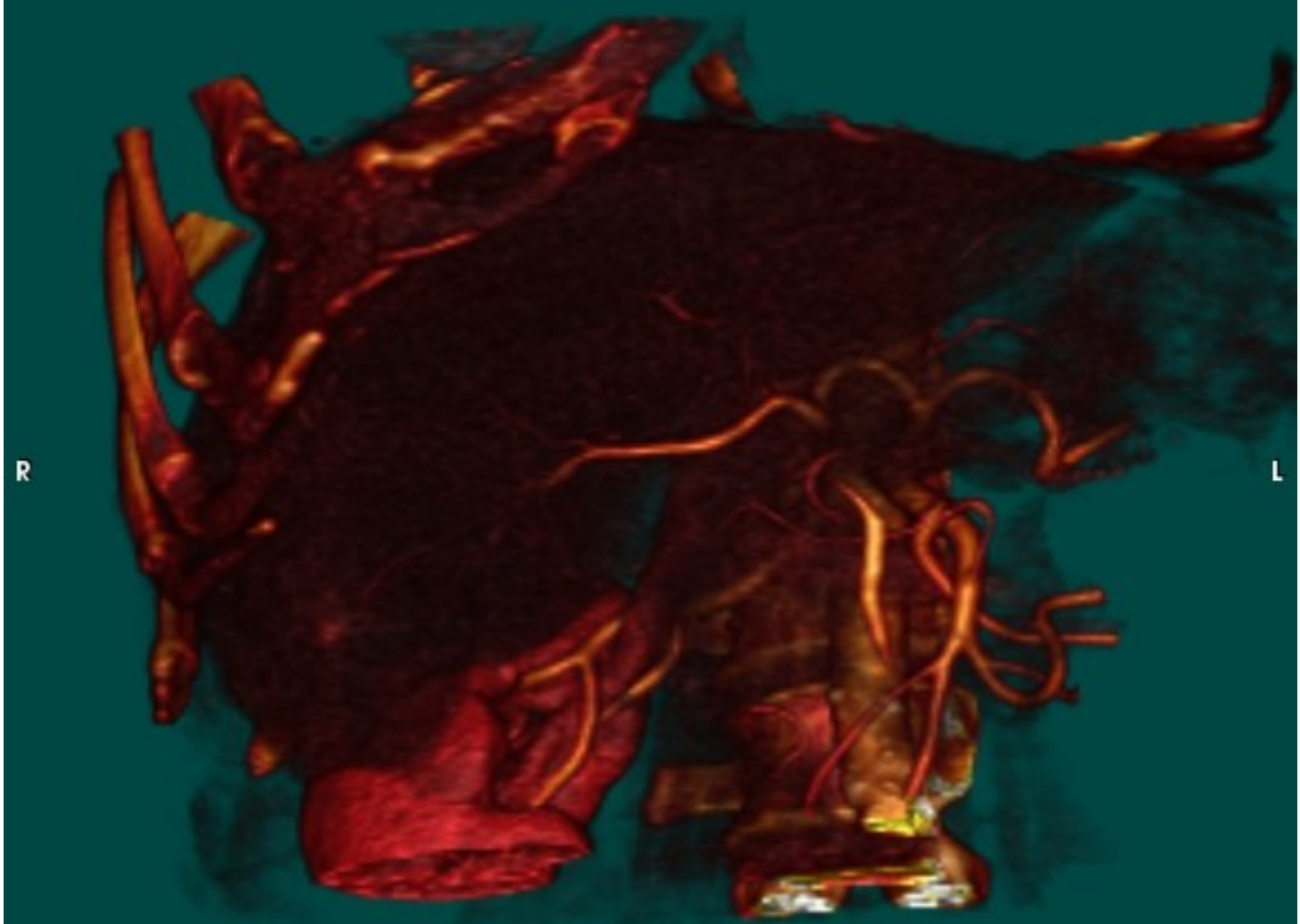
LAI

X

IAR







R

L

X

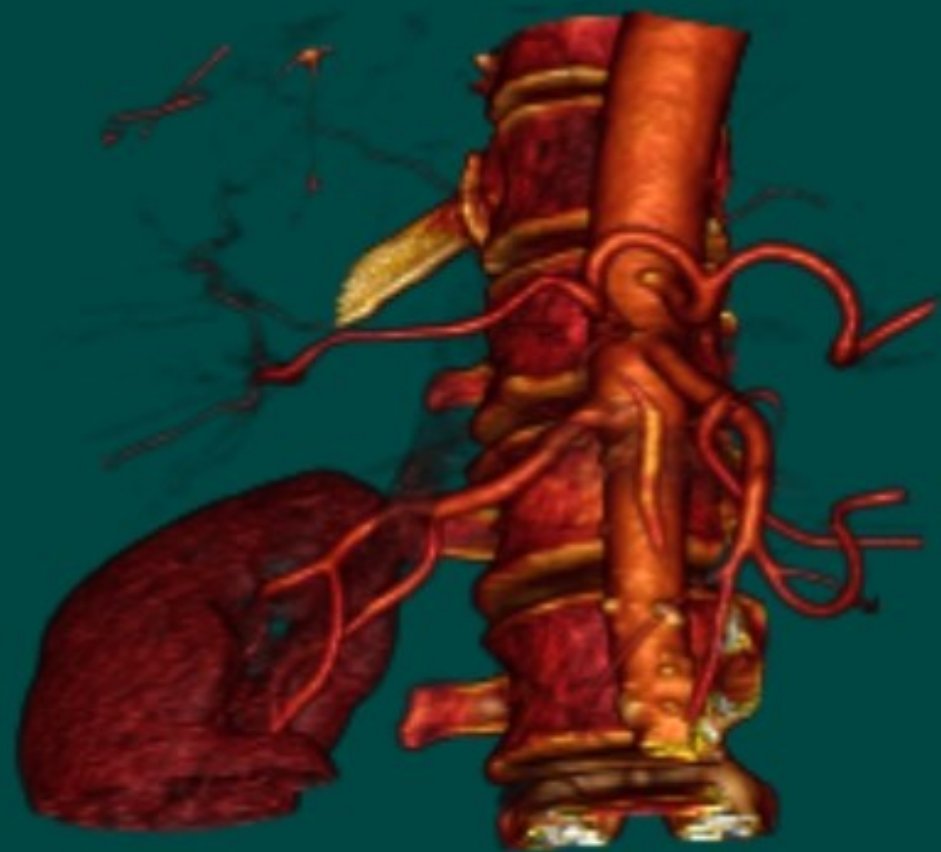
IP





R

L



X

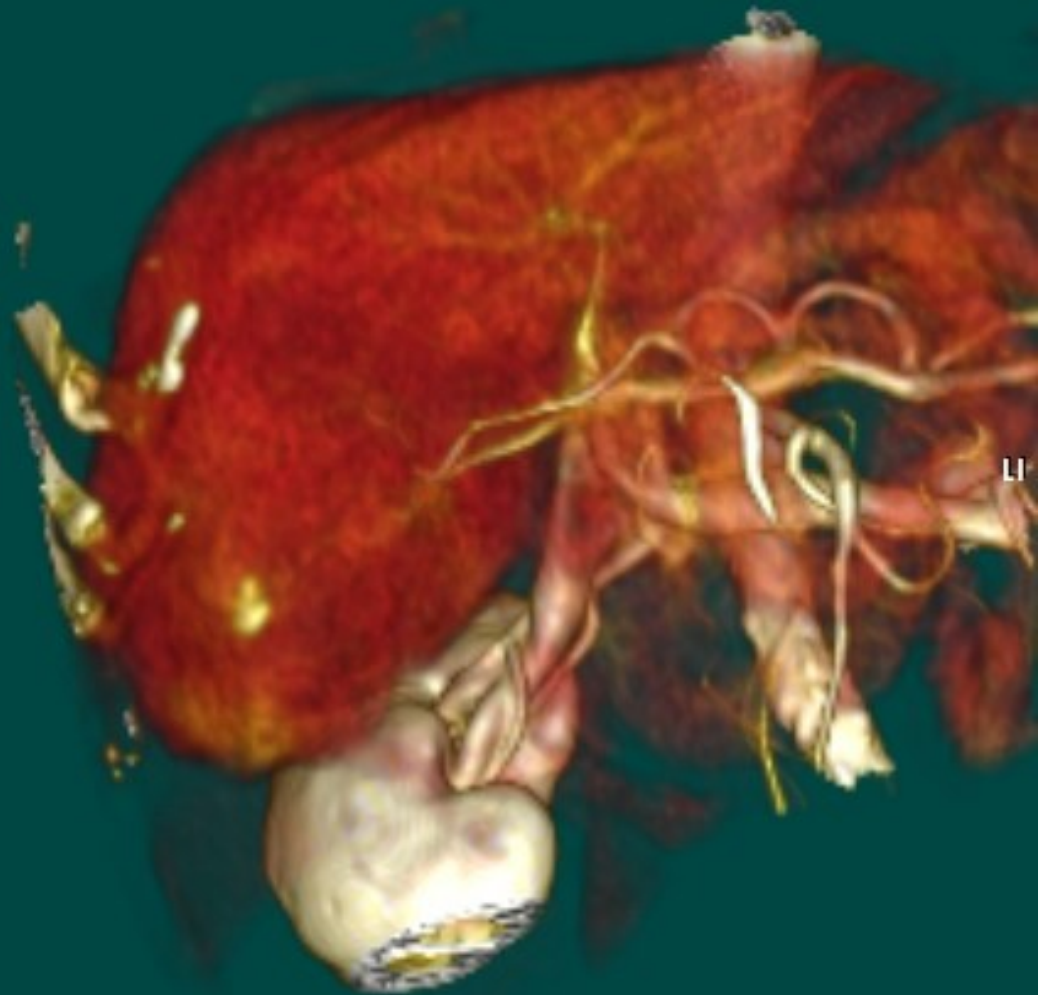
IP





RS

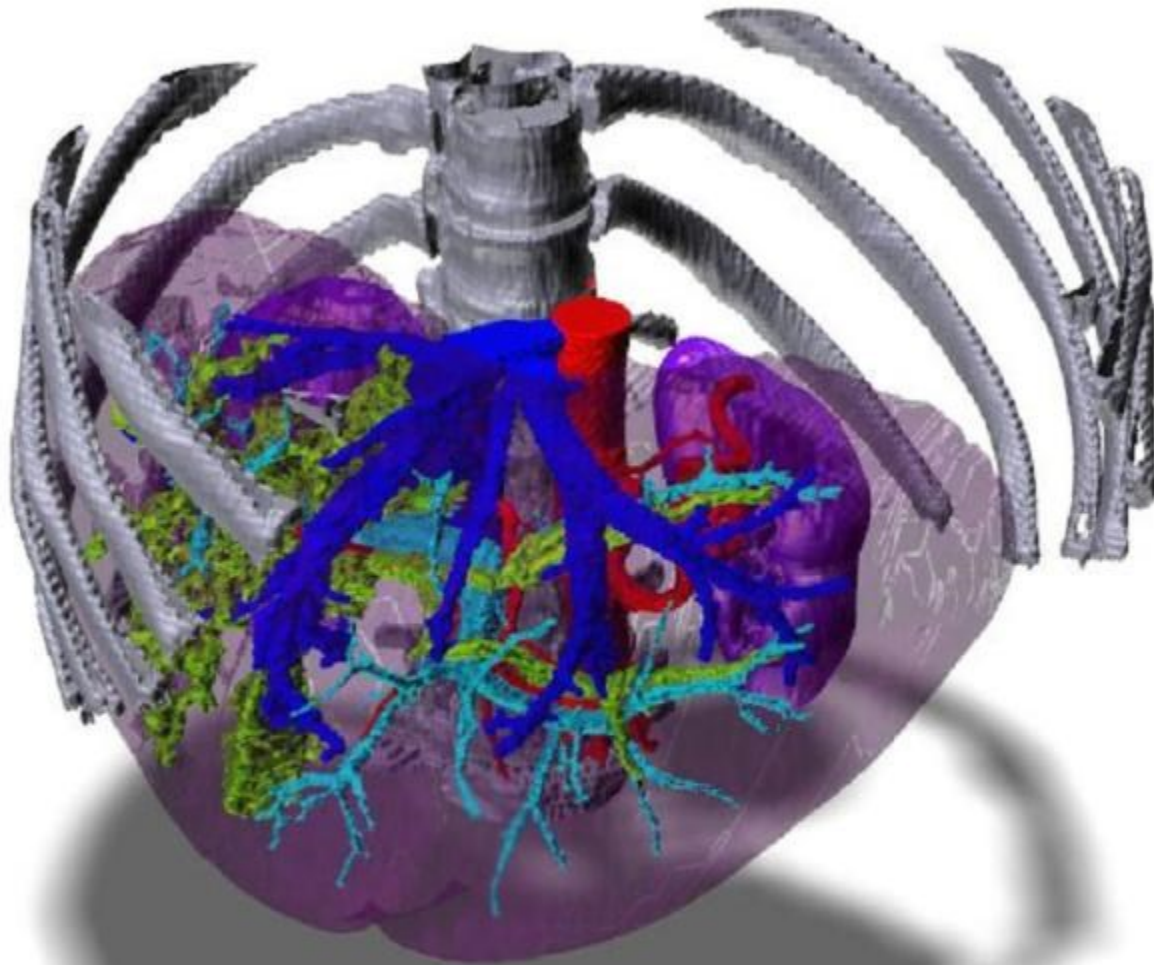
LI



X

IPR





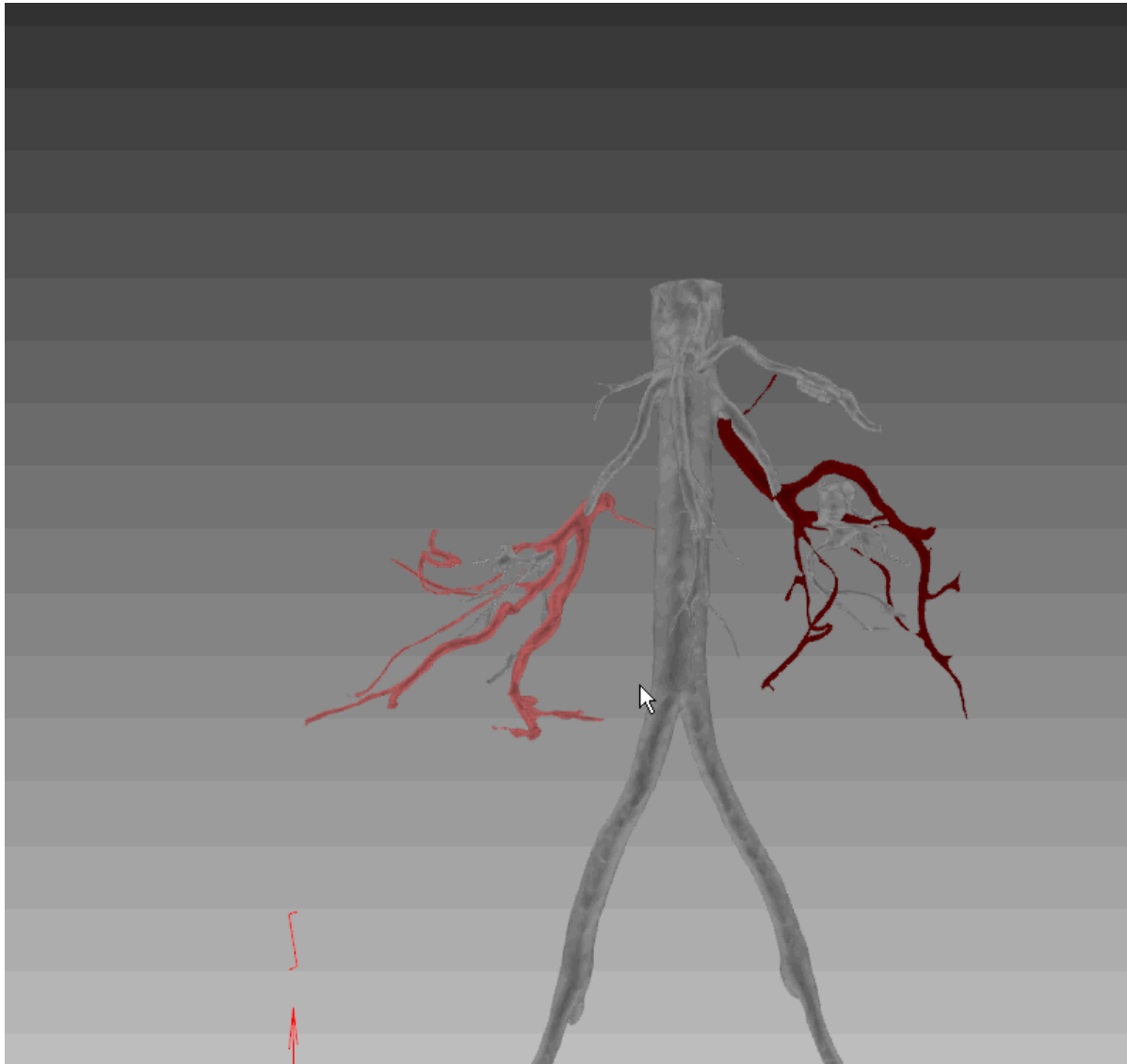
La segmentazione non solo per la visualizzazione...



...si ha una descrizione geometrica delle strutture...



...che permette di pianificare l'intervento



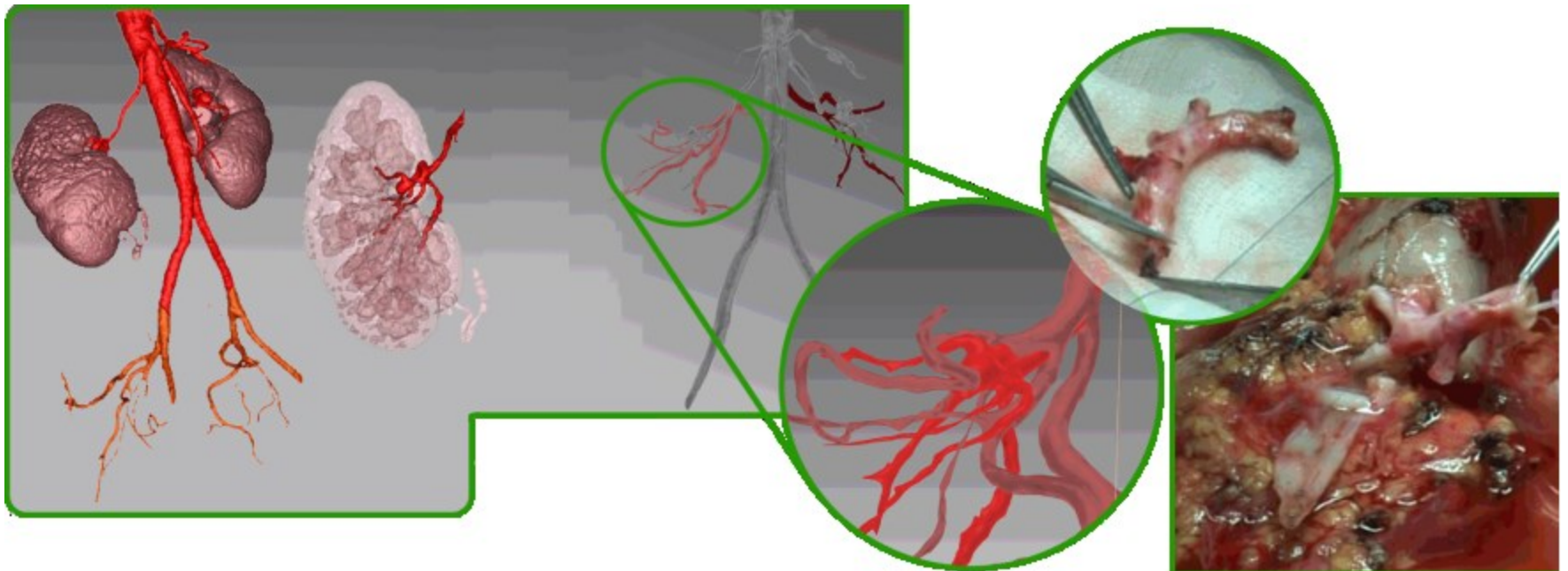
Renal autotransplant

Patient: 38-year-old (F)

Pathology: fibromuscular dysplasia - causing multiple bilateral aneurysms on the renal arteries(RAs)

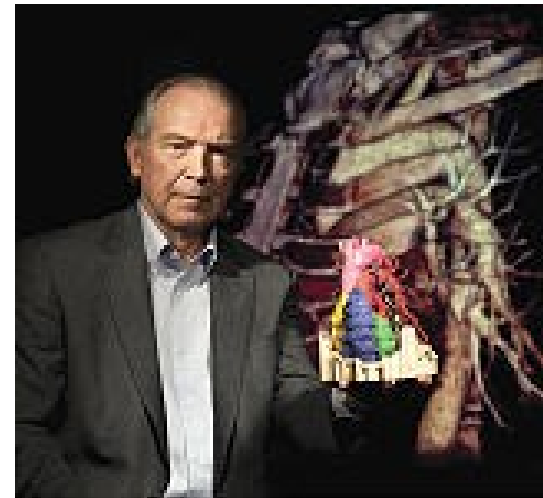
Treatment: The planning allowed the surgical team to manage the entire in-vivo operation laparoscopically and robotically.

The kidney was procured laparoscopically, repaired at a back-table, and transplanted by robot-assisted laparoscopy.



- Automated and accurate segmentation is one of the “holy grail” of CAD and CAS

R. A. ROBB, “Biomedical imaging: Past, present and predictions,” in Proceedings of the First International Symposium on Intelligent Assistance in Diagnosis of Multi-Dimensional Medical Image, 2005.

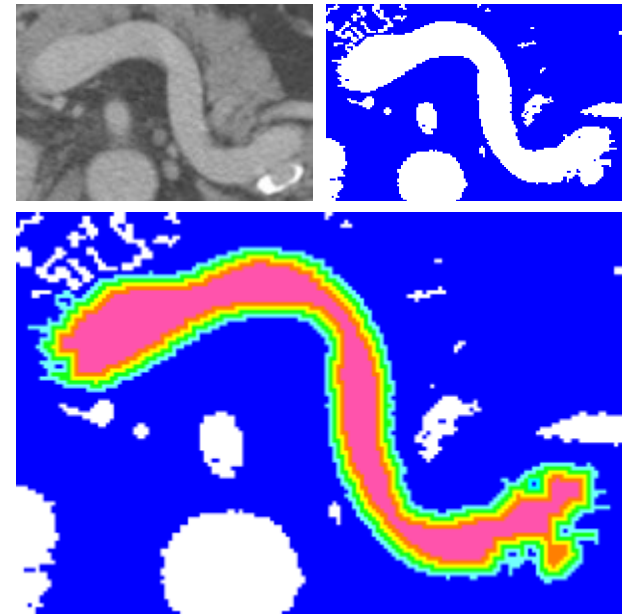


Segmentazione

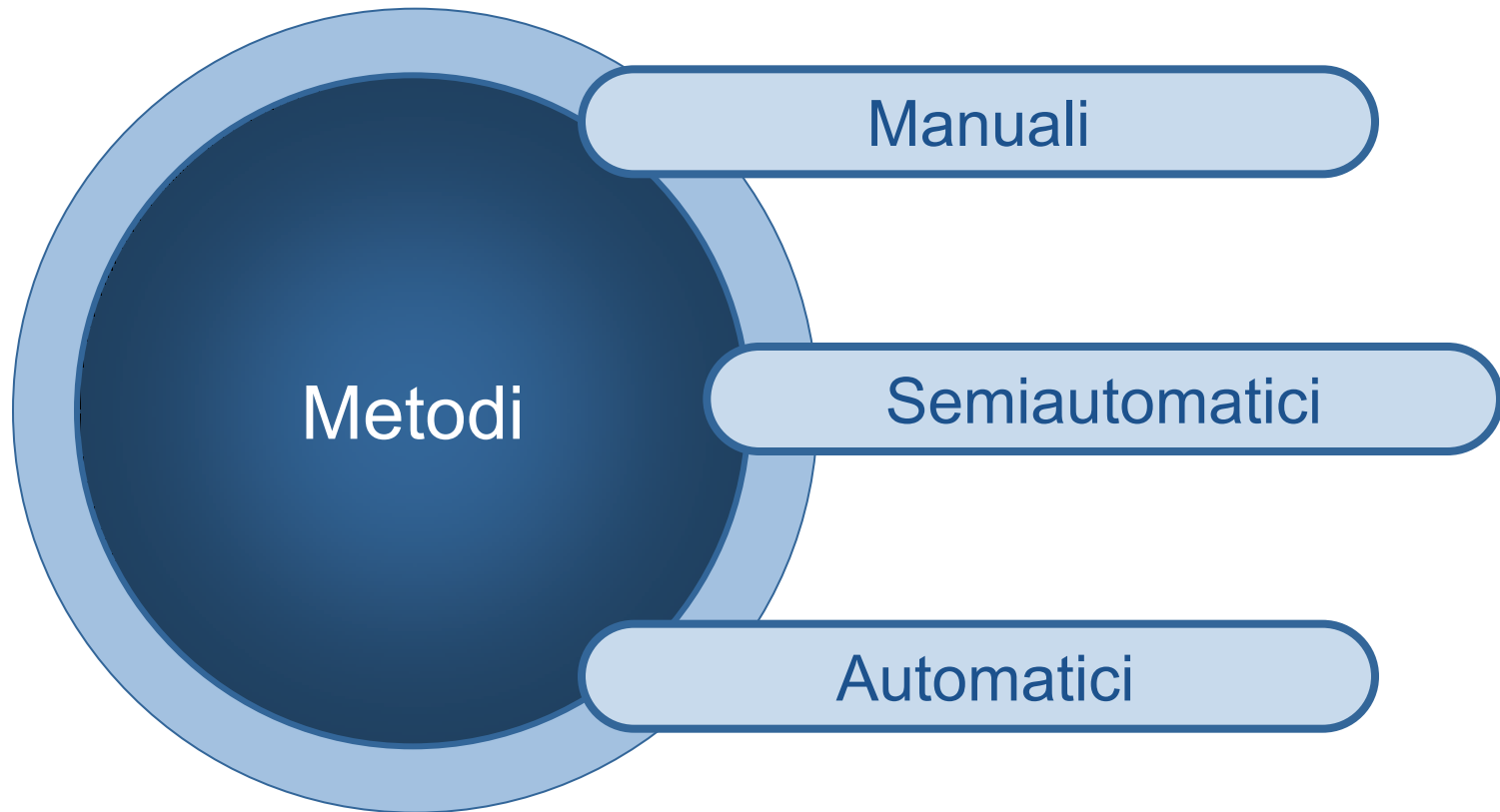
Partizionamento di un'immagine digitale in segmenti al fine di facilitare e rendere più completa l'analisi.

Esistono vari metodi:

- Thresholding
- Clustering
- Histogram-based
- Edge detection
- Region growing
- Split & Merge
- Parametrici...



Segmentazione



Segmentation: software tools

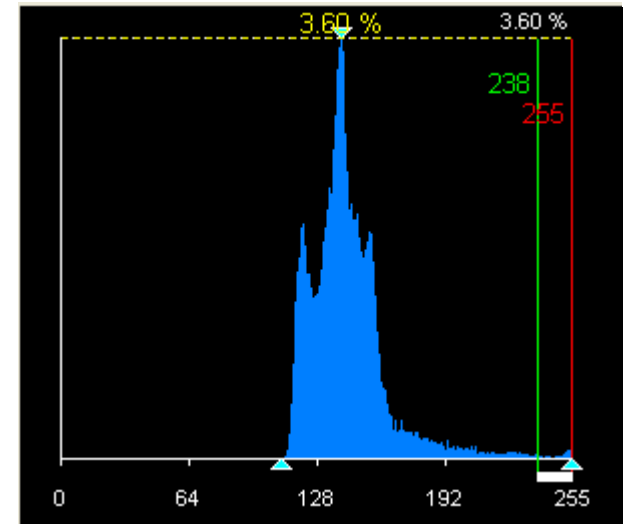
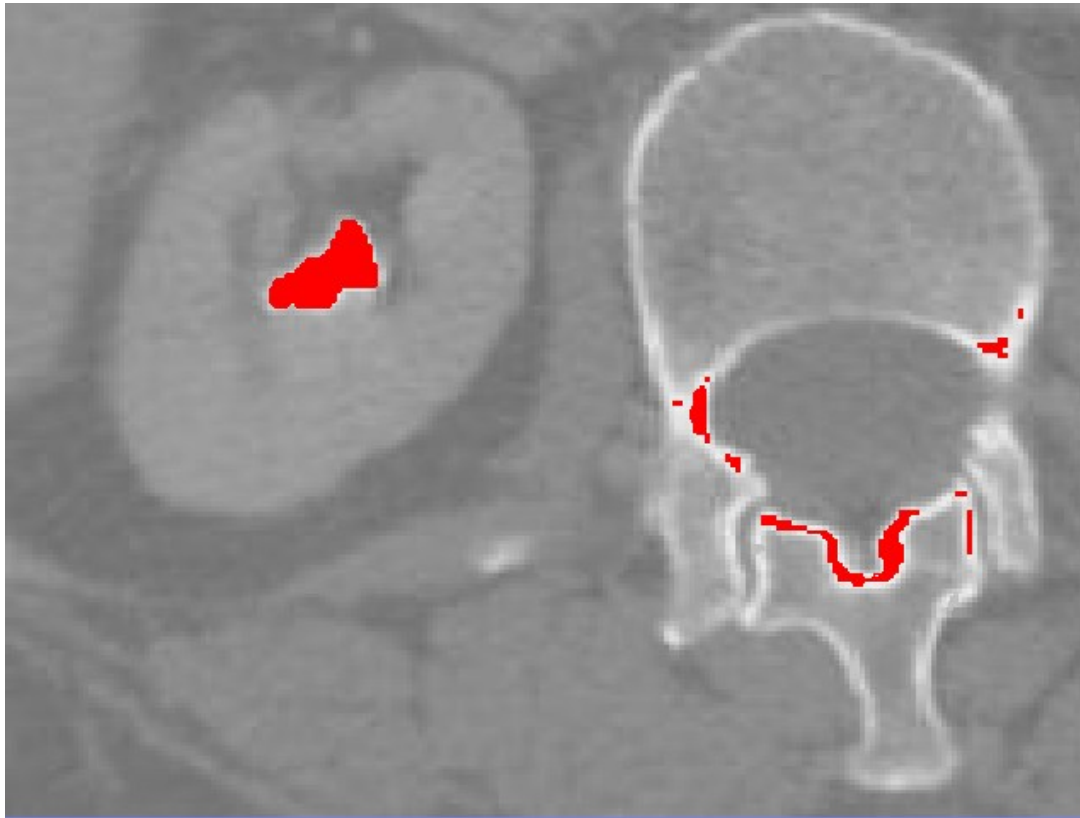
Tools for specific districts:

- ❑ Mimics - Materialise (automatic, bones, theet)
- ❑ Brain Atlas (automatic, atlas, brain)
- ❑ Mevis (liver, service, region growing with automatic parameters adjusting). Now a visual tool: MevisLab!!!
- ❑ Synapse 3D By Fuji (liver, kidney, neurosurgery)

General purpose tools:

- ❑ ITK-Snap (general purpose, snake, free)
- ❑ 3D slicer (general purpose, multi-phase, free)
- ❑ Amira (general purpose, not free)
- ❑ Osiris (general purpose, free)
- ❑ Analyze (general purpose, not free)

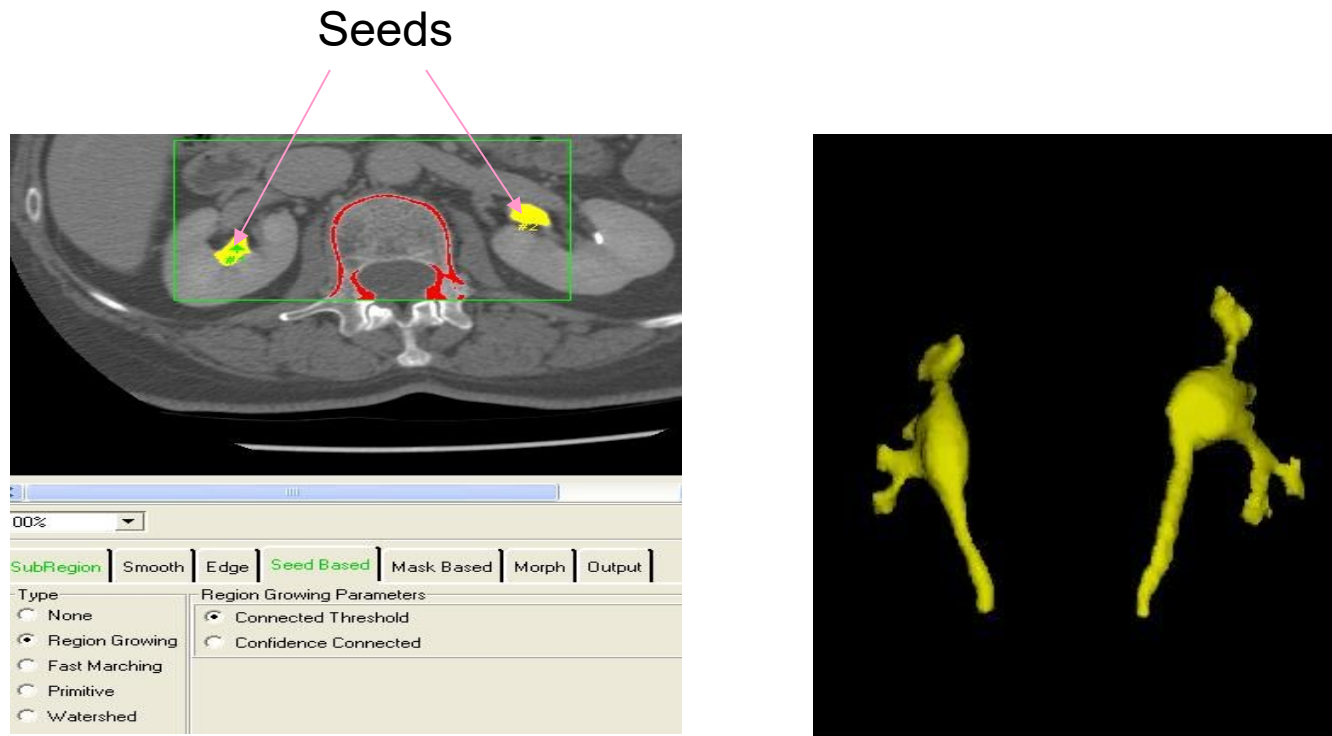
Segmentation: thresholding



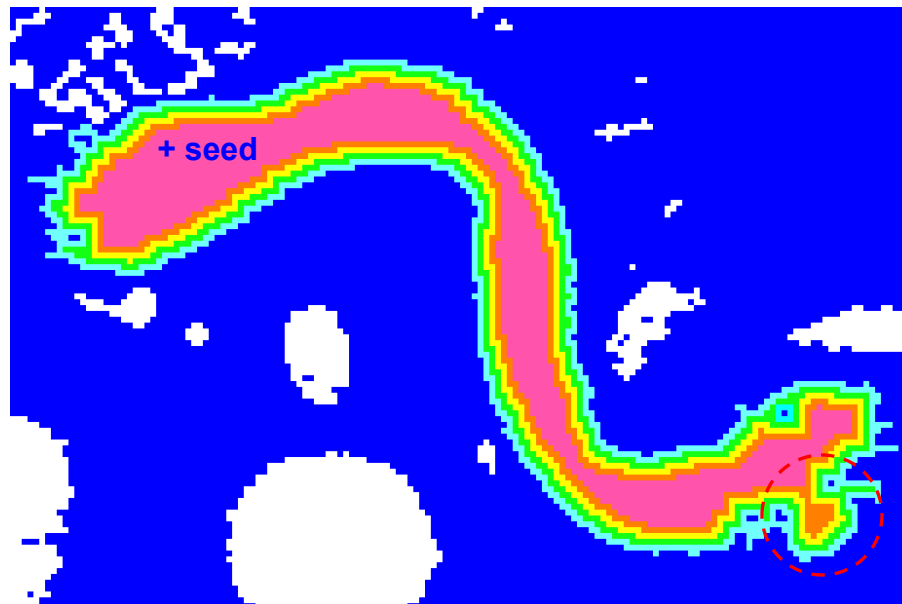
Thresholding

Segmentation: region growing

- Choose a number of seed regions
- Grow the regions provided that certain criteria are satisfied

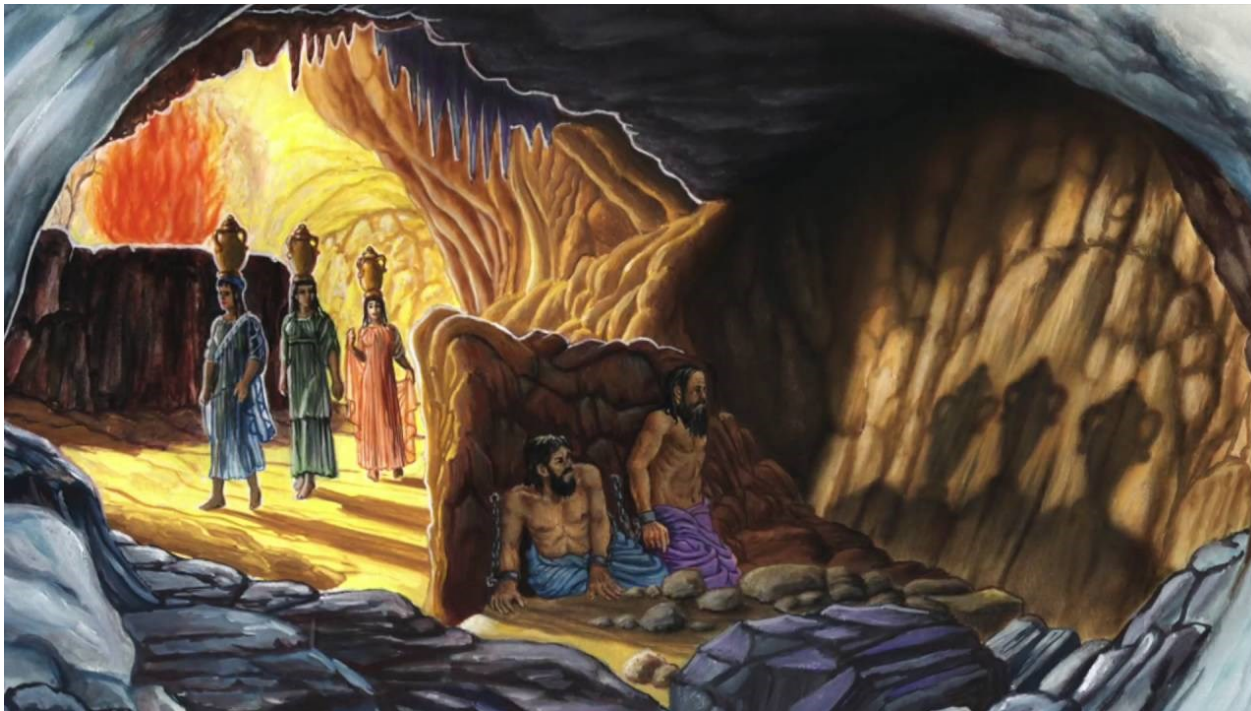
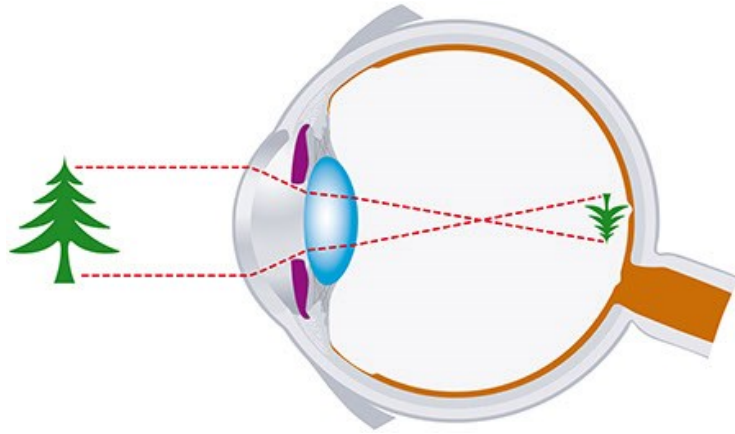


Neighborhood connected region growing

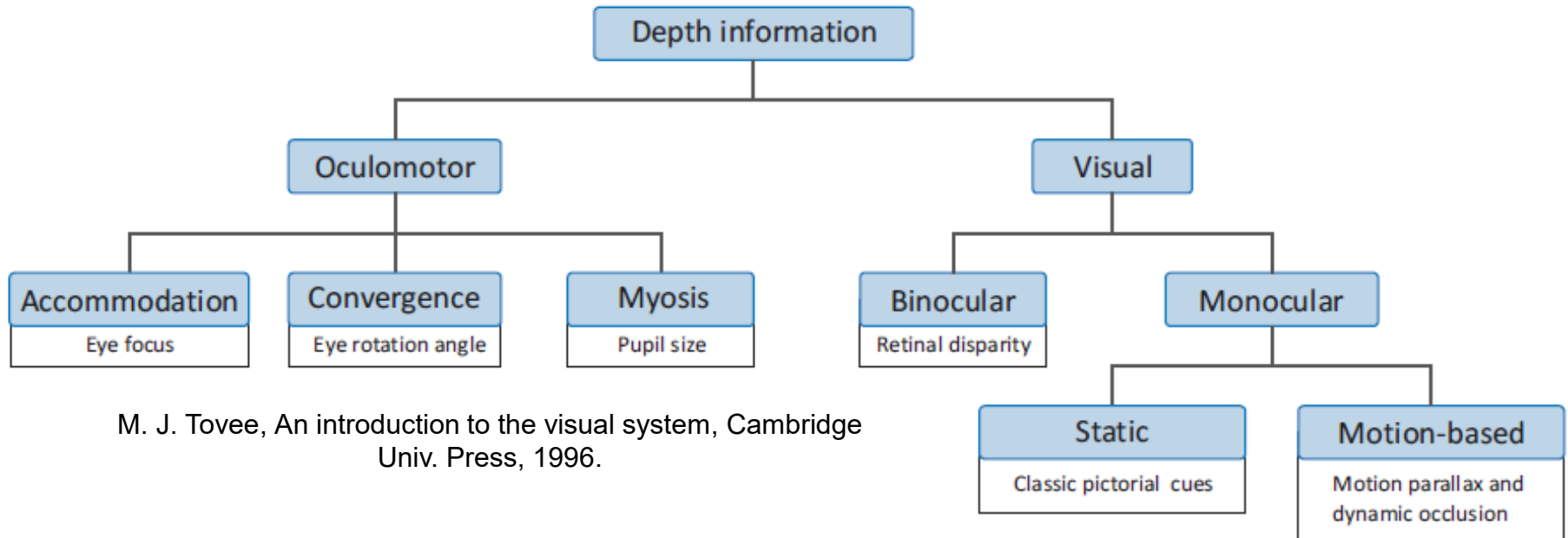


- ITK-Snap
- TC multifase; sistemi di riferimento; «immagine» con la segmentazione.
- Passaggi di raffinamento della superficie.
- Tagli: fatti sul volume discretizzato e segmentato e non sulle superfici.

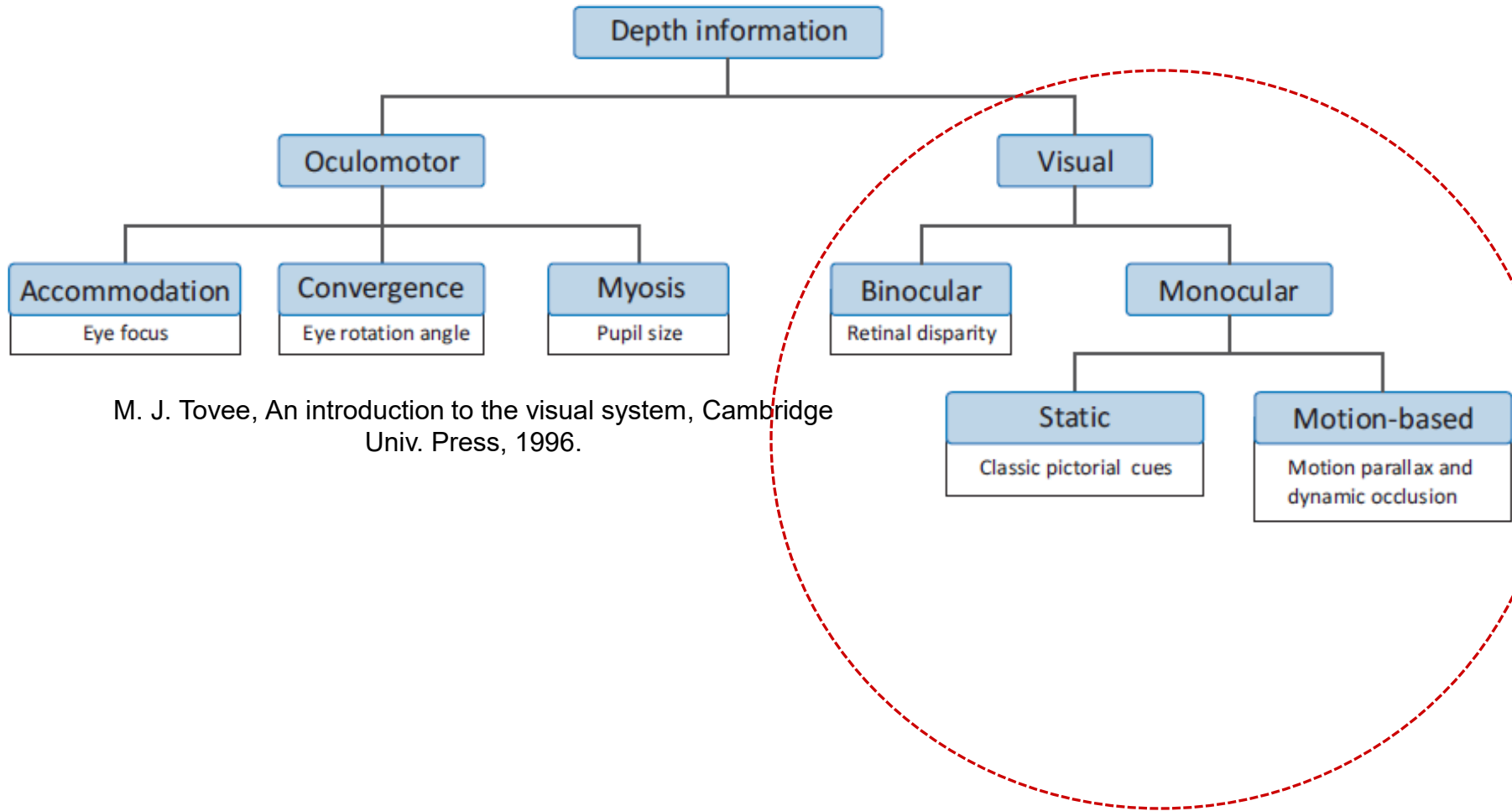
Depth Perception: Ill-Posed Problem



Depth Perception in Human Visual System



Depth Perception in Human Visual System



M. J. Tovee, An introduction to the visual system, Cambridge Univ. Press, 1996.

Visual Depth Cues → Monocular → Static

Occlusioni o interposizioni spaziali: le occlusioni forniscono una primitiva forma di prospettiva lineare alla scena e ci danno informazioni sulle relazioni di profondità tra più oggetti. L'oggetto che si vede sarà necessariamente più vicino a quello occluso.

Dimensione retinica & familiare: Se il nostro cervello riconosce due oggetti come aventi la stessa dimensione, interpreterà come più lontano quello che stimola una minor porzione della retina.

Visual Depth Cues → Monocular → Static

Chauvet Cave (Ardèche department, South of France). Paintings were dated between 32000 and 30000 years old.



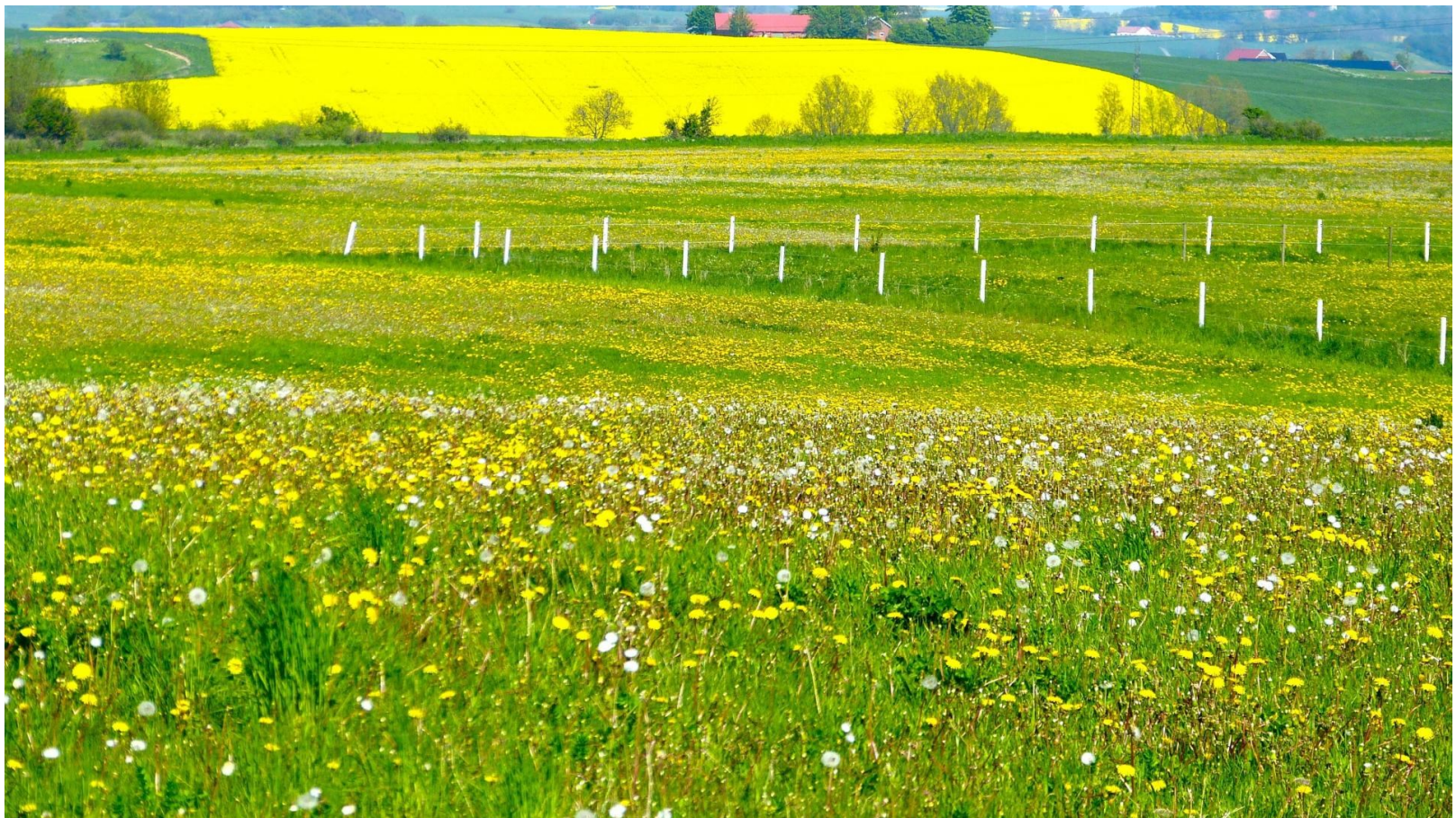
Dimensione
retinica e familiare

**Occlusions- Occlusions-
Chromadepth Chromadepth**

**Retinal Size
Retinal Size**

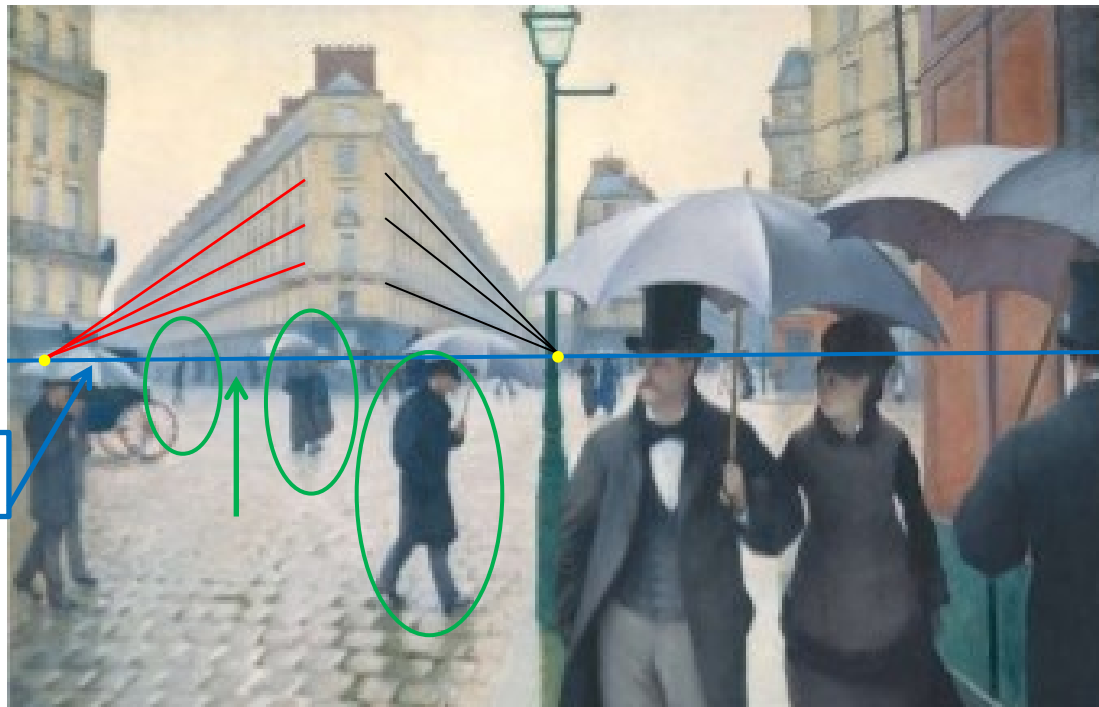
Visual Depth Cues → Monocular → Static

Gradiente di tessitura: gli elementi caratterizzanti la tessitura dell'immagine, cioè i fili d'erba, le pietre, il pavimento etc. sono più diradati e meno definiti più ci si allontana dall'osservatore. Tale indicatore funziona bene in presenza di serie di elementi aventi uguale struttura, dimensione e spaziatura nella scena.



Visual Depth Cues → Monocular → Static

Prospettiva lineare: Legato sia al gradiente di tessitura che alle dimensioni relative tra oggetti, questo indicatore è legato alla proprietà di rette parallele nella scena che non sono parallele al piano retinico di convergere all'infinito (vanishing point).



Linea orizzonte

Altezza sul piano dell'orizzonte: più un oggetto è vicino alla linea dell'orizzonte più ci sembra lontano.

Visual Depth Cues → Monocular → Static



Visual Depth Cues → Monocular → Motion Parallax

Motion Parallax: Relative motion between observer and scene creates motion parallax over time and provides depth perception. Objects in the scene appear moving at different velocities depending on their distance from the observer.

Motion Parallax
Motion Parallax

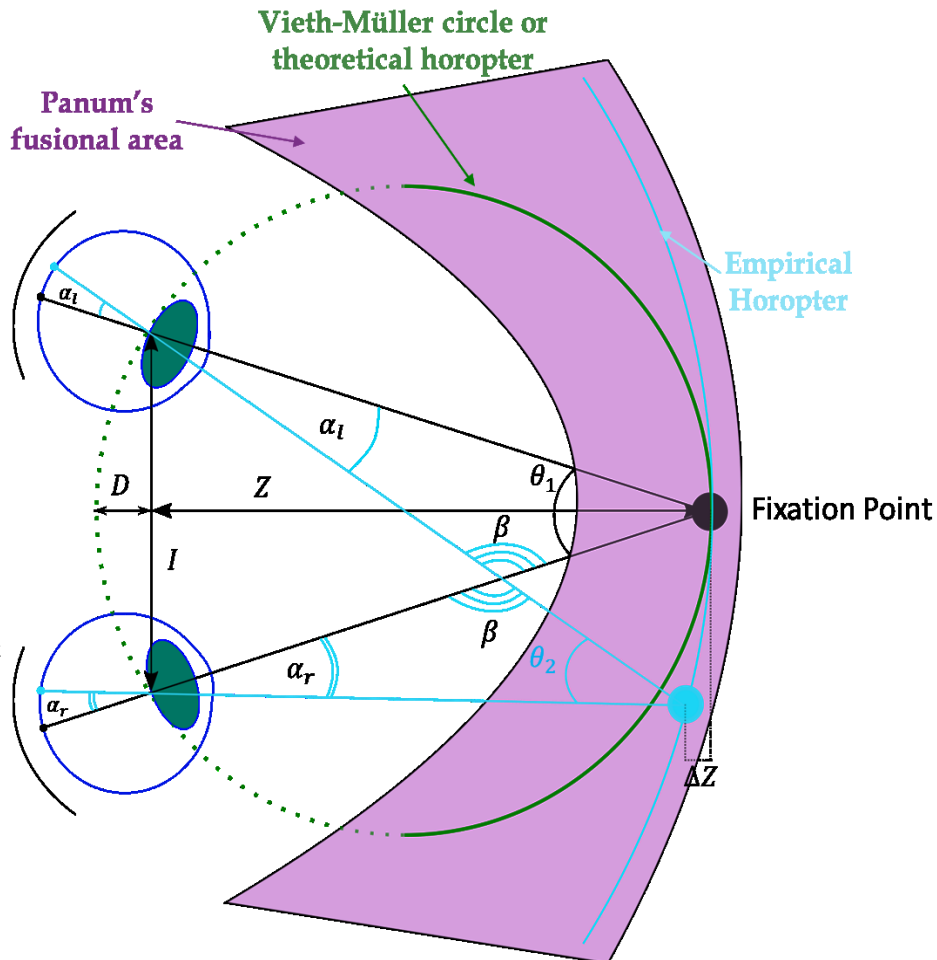
Visual Depth Cues → Binocular → Binocular Parallax

Dato un fixation point, l'equazione che lega l'angolo di convergenza tra gli occhi θ alla distanza interoculare è: $\theta = 2 \tan^{-1}(I/2Z)$ da cui derivando rispetto a Z si ha la formula della risoluzione di profondità:

$$\Delta Z_h = -\frac{Z^2}{I} \left(1 + \frac{I^2}{4Z^2}\right) \Delta\theta \approx -\frac{Z^2 * \Delta\theta}{I}$$

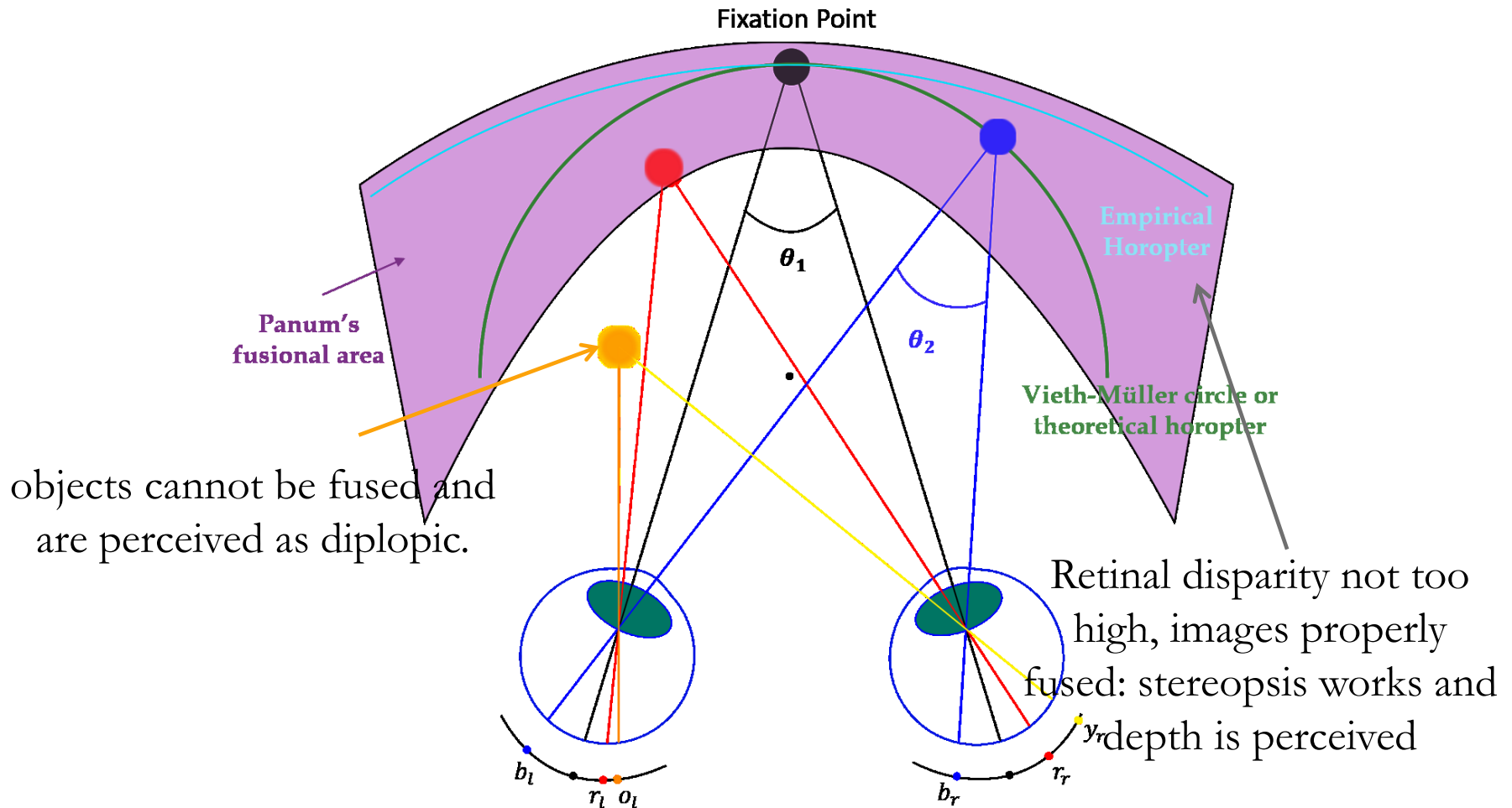
Da semplici considerazioni geometriche,
 $\Delta\theta = \theta_1 - \theta_2 = (\pi - \beta - \alpha_l) - (\pi - \beta - \alpha_r) = \alpha_r - \alpha_l = -\Delta\alpha$
 Quindi la risoluzione di profondità è strettamente legata alla differenza angolare retinica (al max acuità stereoscopica) tramite la distanza interpupillare e la distanza tra fixation point ed osservatore:

$$\Delta Z_h \approx \frac{Z^2 * \Delta\alpha}{I}$$

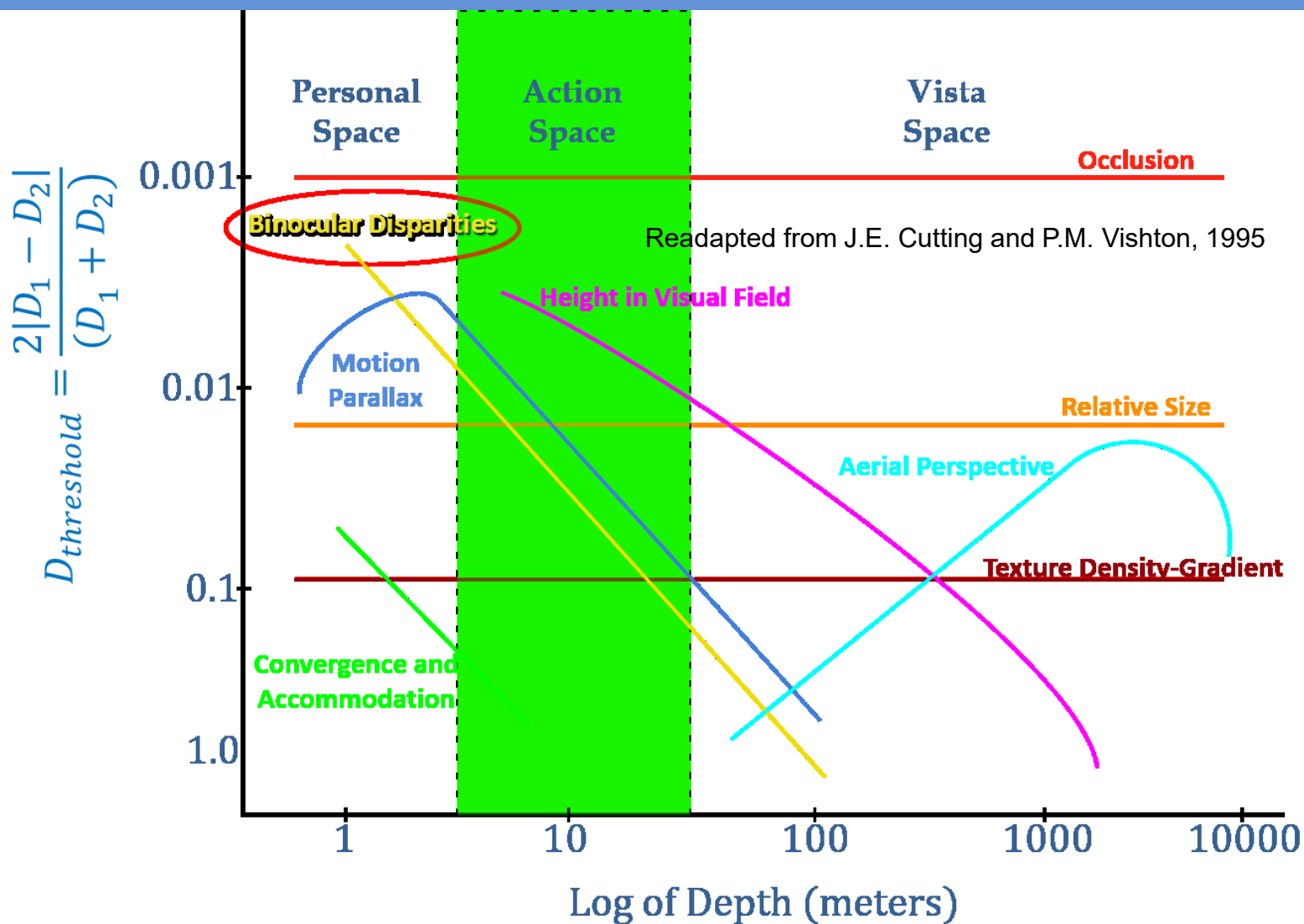


Horopter and Panum's area

Per costruzione (Teorema della corda) tutti i punti dello spazio ϵ oroptero ideale producono 0 disparità retinica ovvero stimolano punti retinici corrispondenti.



Classification of Depth Cues in Relation to their acting distance



3D DISPLAYS

Two-view

<i>Eyeglasses</i>	<i>Stereoscopes</i>	<i>Autostereoscopic</i>
<i>Wavelength selective</i> Wavelength selective glasses [5]	<i>Two-view HMD</i> HMD using HOE [10] HMD using diffractive grating element [9]	<i>Time sequential</i> Prism film, switching backlight [14]
<i>Time sequential</i> ZScreen circular polarisation [13] ALPS linear polarisation [13]	<i>Volumetric HMD</i> Multi-planar volumetric HMD [65]	<i>Time parallel</i> Polarisation activated microlens [18] Bulk optics twin LCD [20,21] Tracked two view, one viewer [22,24] Tracked two views, many viewers [25]
<i>Time parallel</i> Twin-LCD polarising with half-mirror [16]		

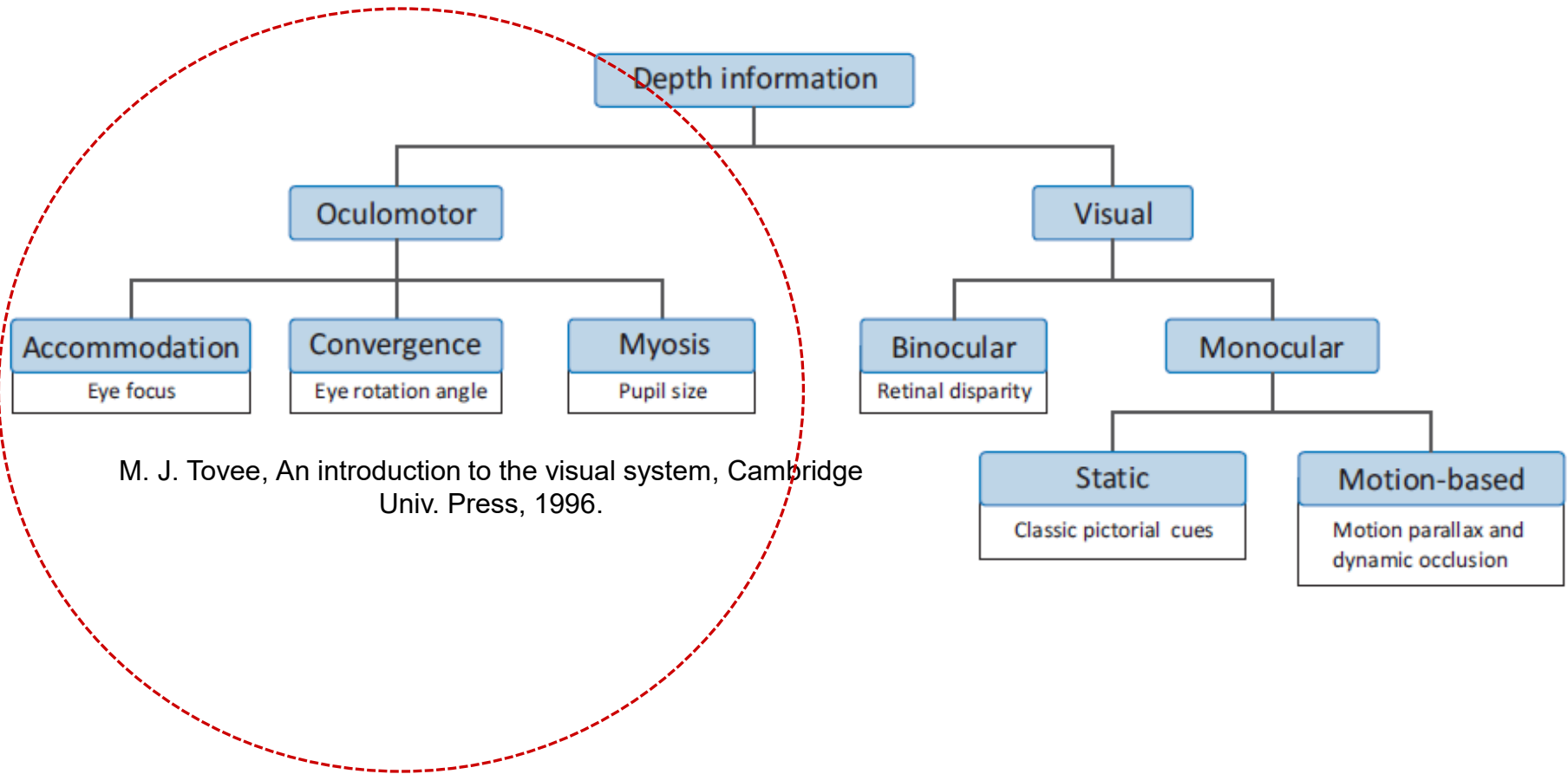
IEEE TRANSACTIONS ON BROADCASTING 57(2), JUNE 2011, PP. 362-371, DOI: 10.1109/TBC.2011.2130930

Three-Dimensional Displays: A Review and Applications Analysis

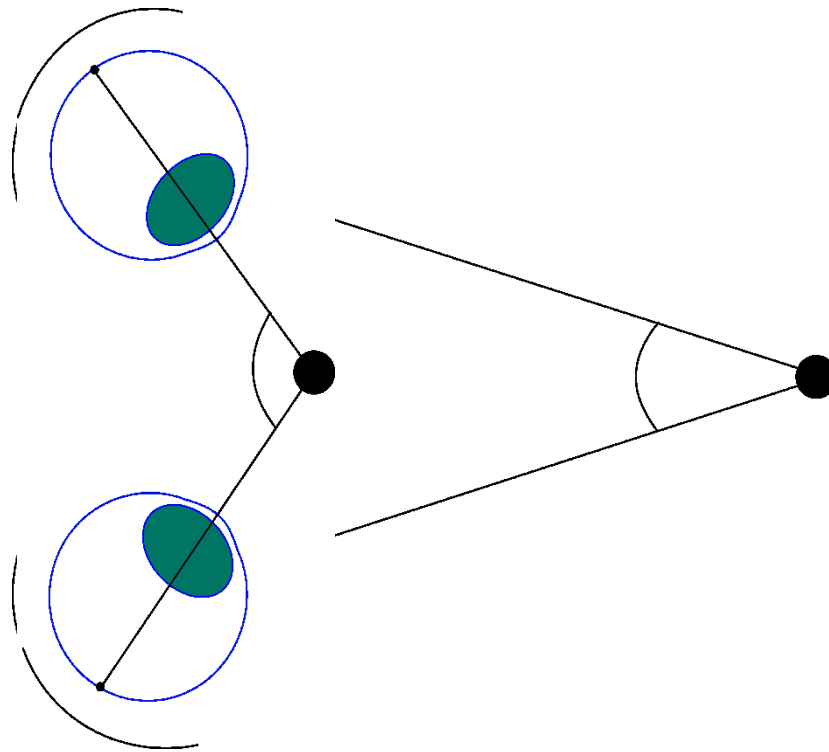
Nicolas S. Holliman, Neil A. Dodgson, Gregg E. Favalora, and Lachlan Pockett

http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5754618&tag=1

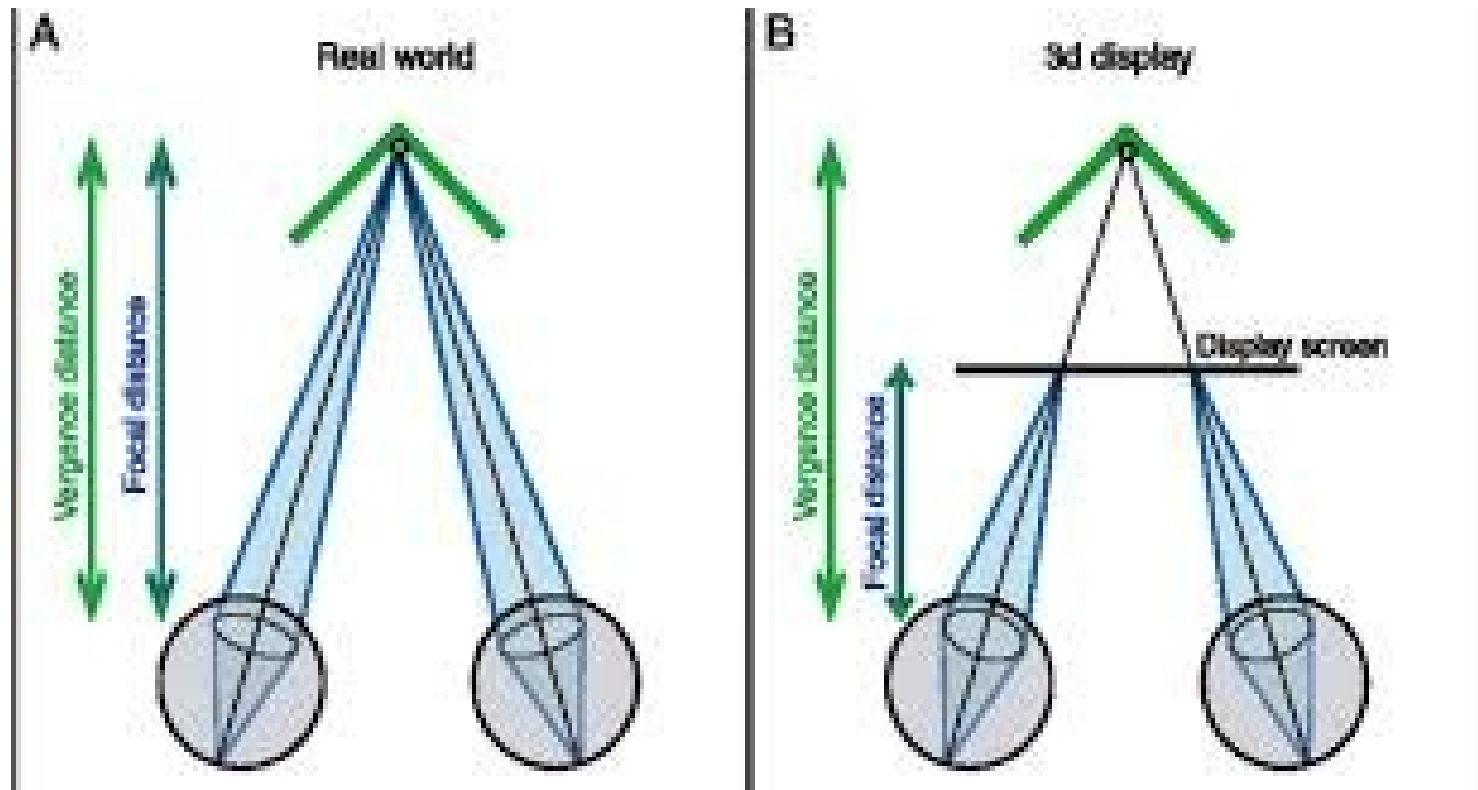
Depth Perception in Human Visual System



Oculomotor Depth Cues → Accommodation/Convergence



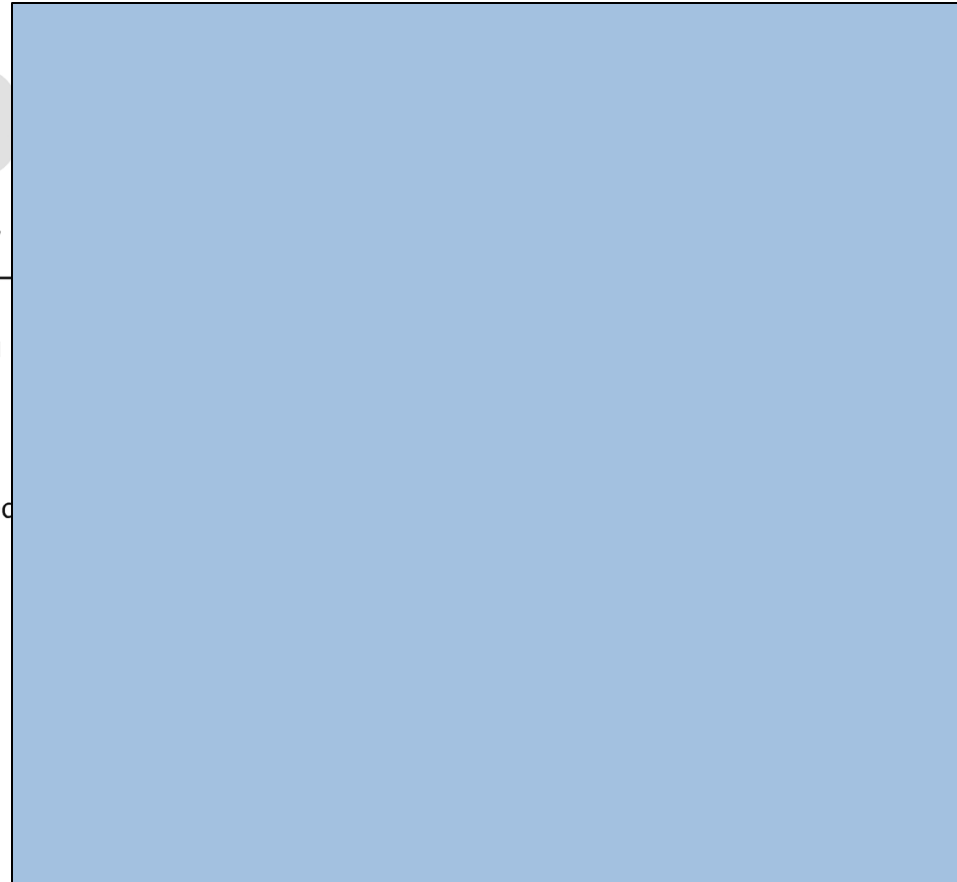
Perceptual Problems on stereoscopic Displays



3D DISPLAYS

Two-view

<i>Eyeglasses</i>	<i>Stereoscopes</i>	<i>Autostereoscopic</i>
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<i>Time sequential</i> ZScreen circular polarisation [13] ALPS linear polarisation [13]	<i>Volumetric HMD</i> Multi-planar volumetric HMD [65]	<i>Time parallel</i> Polarisation activated microlens [18] Bulk optics twin LCD [20,21] Tracked two view, one viewer [22,24] Tracked two views, many viewers [25]
<i>Time parallel</i> Twin-LCD polarising with half-mirror [16]		



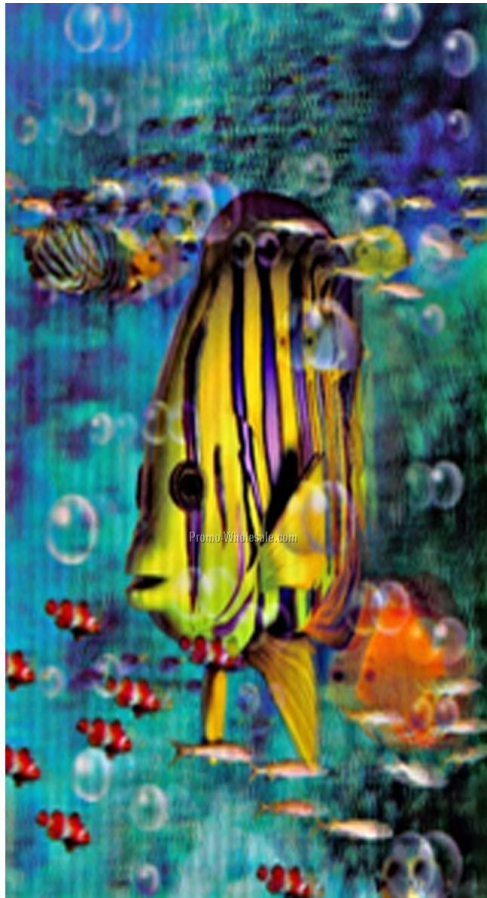
IEEE TRANSACTIONS ON BROADCASTING 57(2), JUNE 2011, PP. 362-371, DOI: 10.1109/TBC.2011.2130930

Three-Dimensional Displays: A Review and Applications Analysis

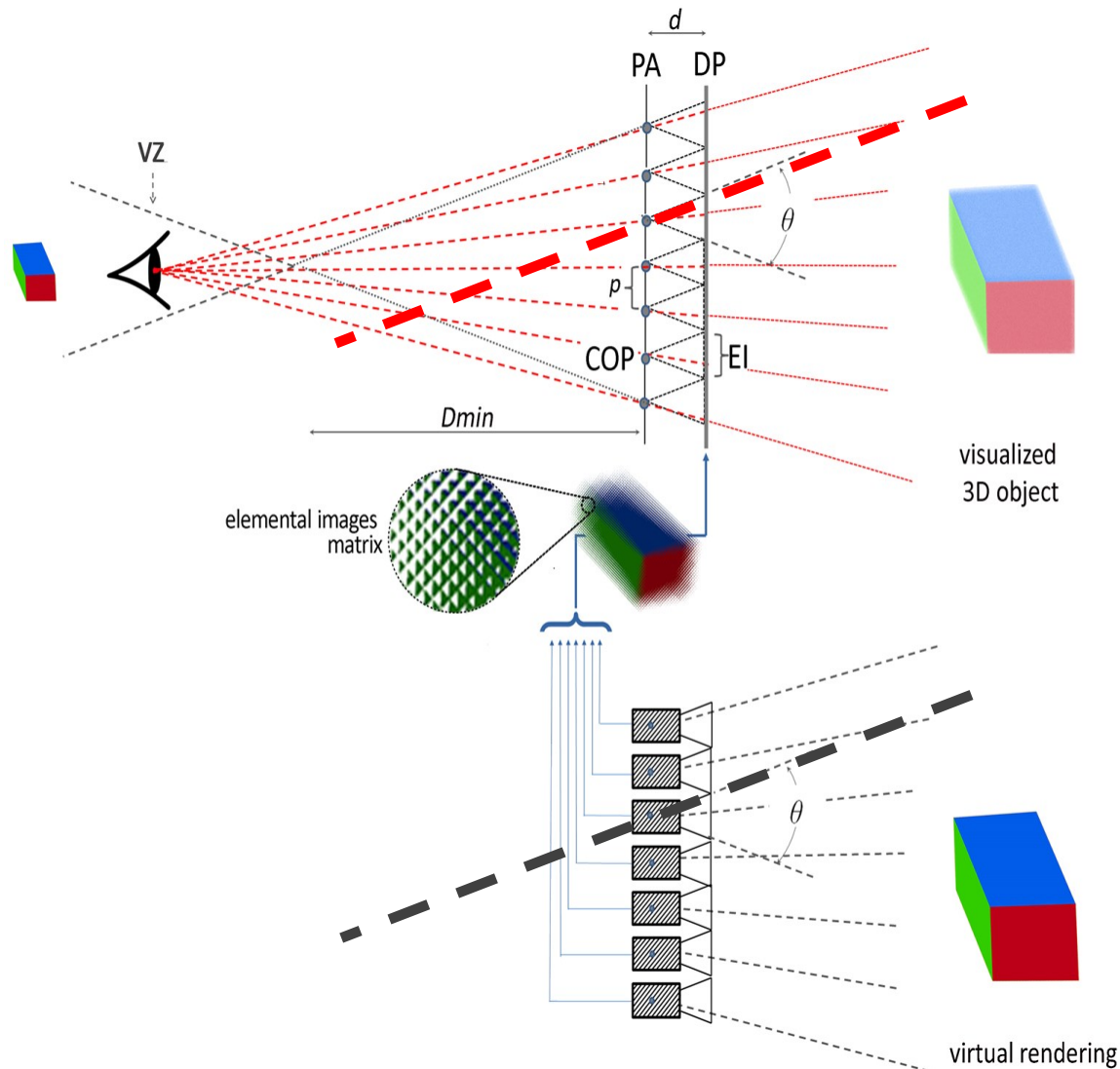
Nicolas S. Holliman, Neil A. Dodgson, Gregg E. Favalora, and Lachlan Pockett

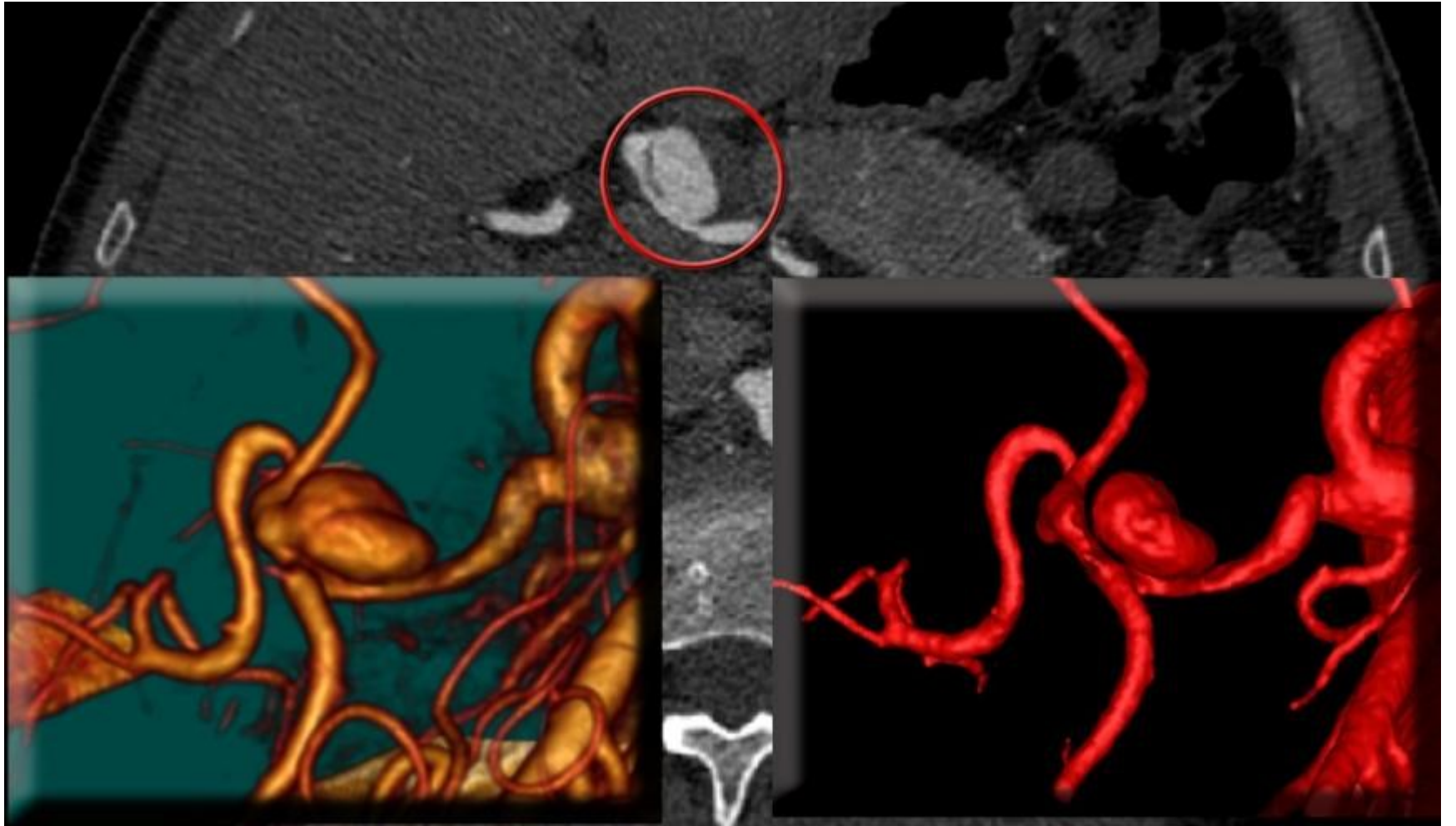
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5754618&tag=1

Integral Imaging → Light Field Display



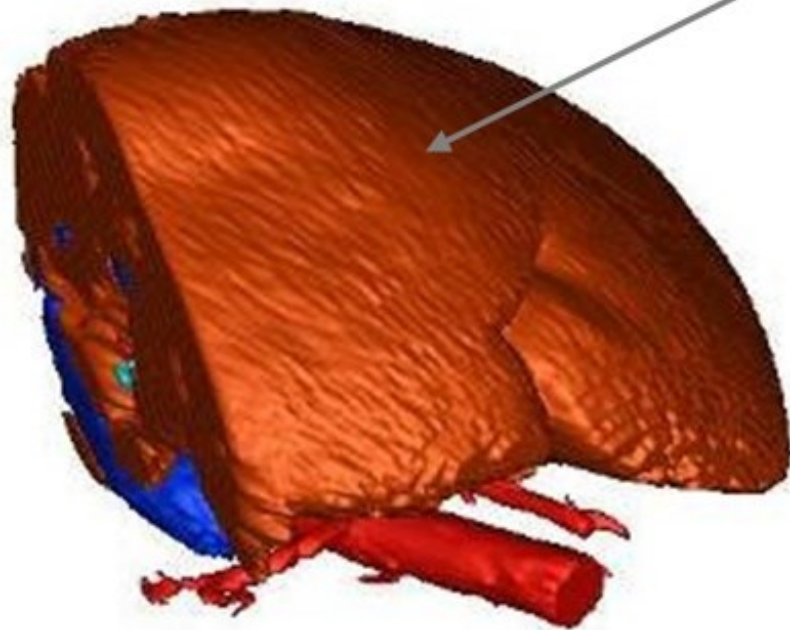
Integral Imaging → Light Field Display





Simulation for liver epatectomy

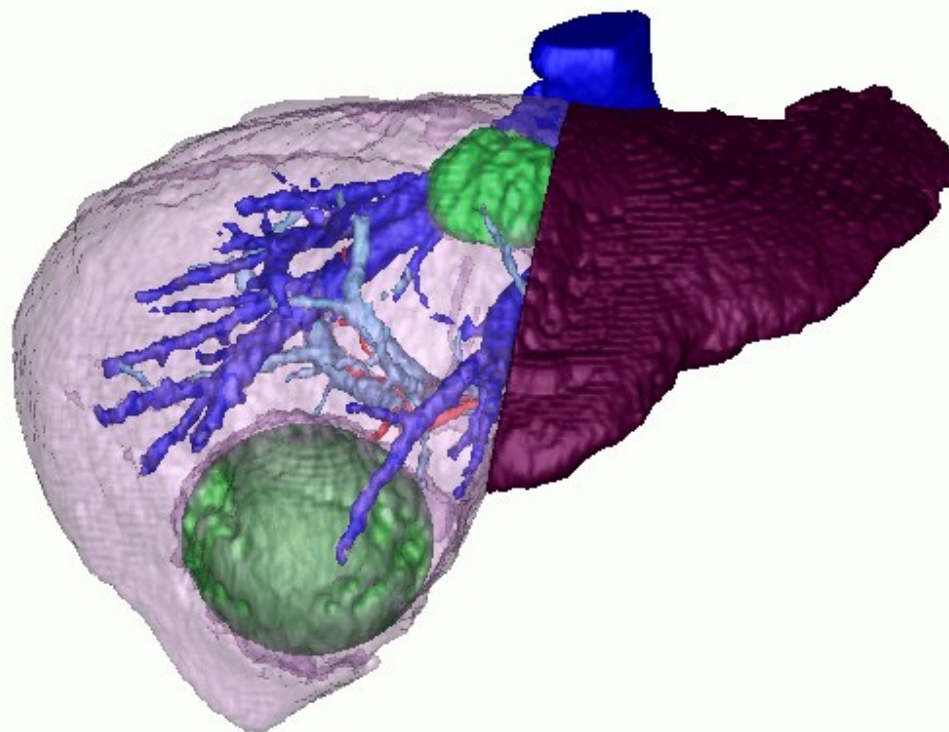




1768cm³

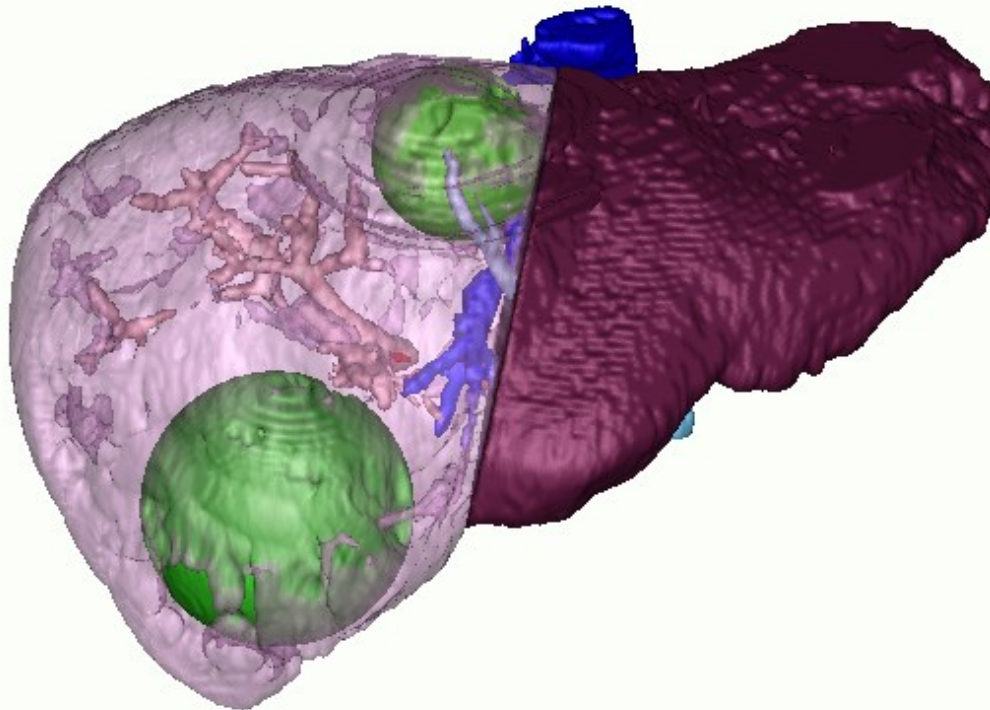
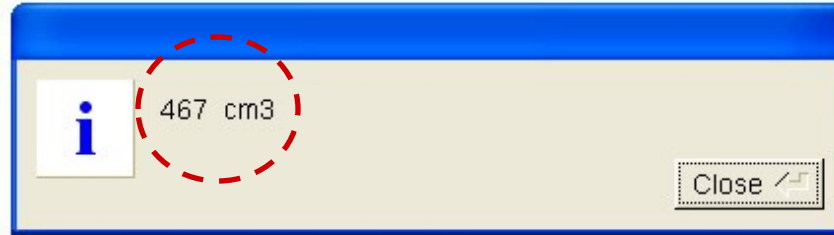


Segmentazione epatica e simulazione chirurgica





Segmentazione epatica e simulazione chirurgica



Synapse 3D by FUJI

Please click the target body region and select an application.



The interface displays a human silhouette on the left with three target body regions highlighted in green: **Head**, **Chest**, and **Abdomen**. To the right, a grid of application icons is organized into two main categories: **General Application** and **Clinical Application**.

General Application includes:

- 2D Viewer
- 3D Viewer
- 4D Viewer
- 3D Comparison
- Dynamic Data
- Fusion
- PET-CT Viewer
- 3D Compositor
- Slicer
- Combination
- 2D Fusion

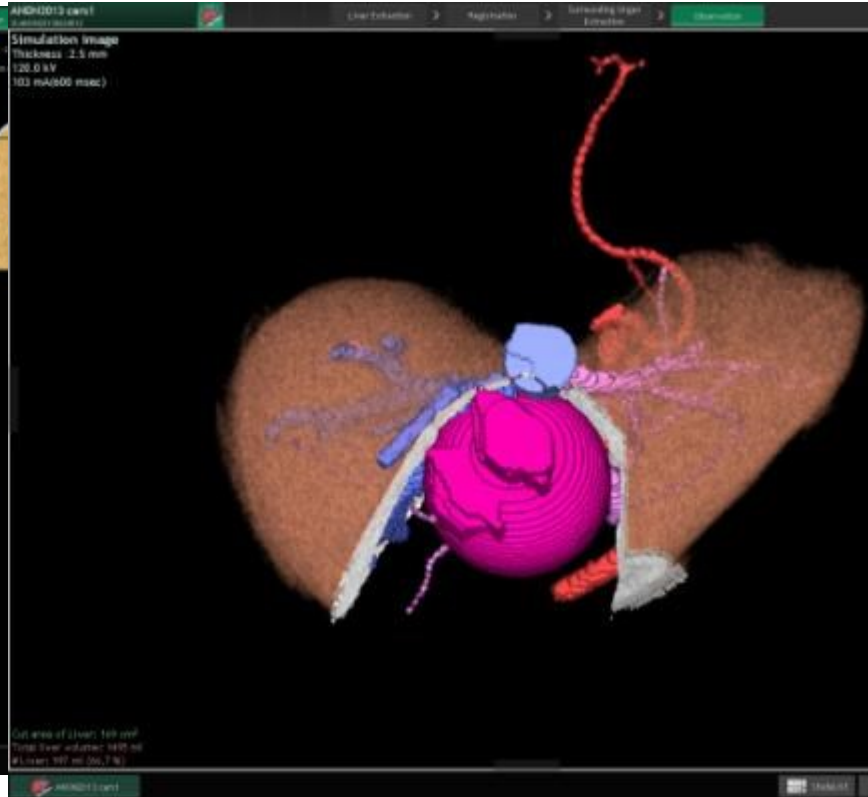
Clinical Application includes:

- Sector MPR
- Liver Analysis
- 2D Fat Analysis
- 3D Fat Analysis
- RECIST Tracker
- PERCIST Tracker

Surgical Planning

Case 1: **Low Tumor 10.8%**

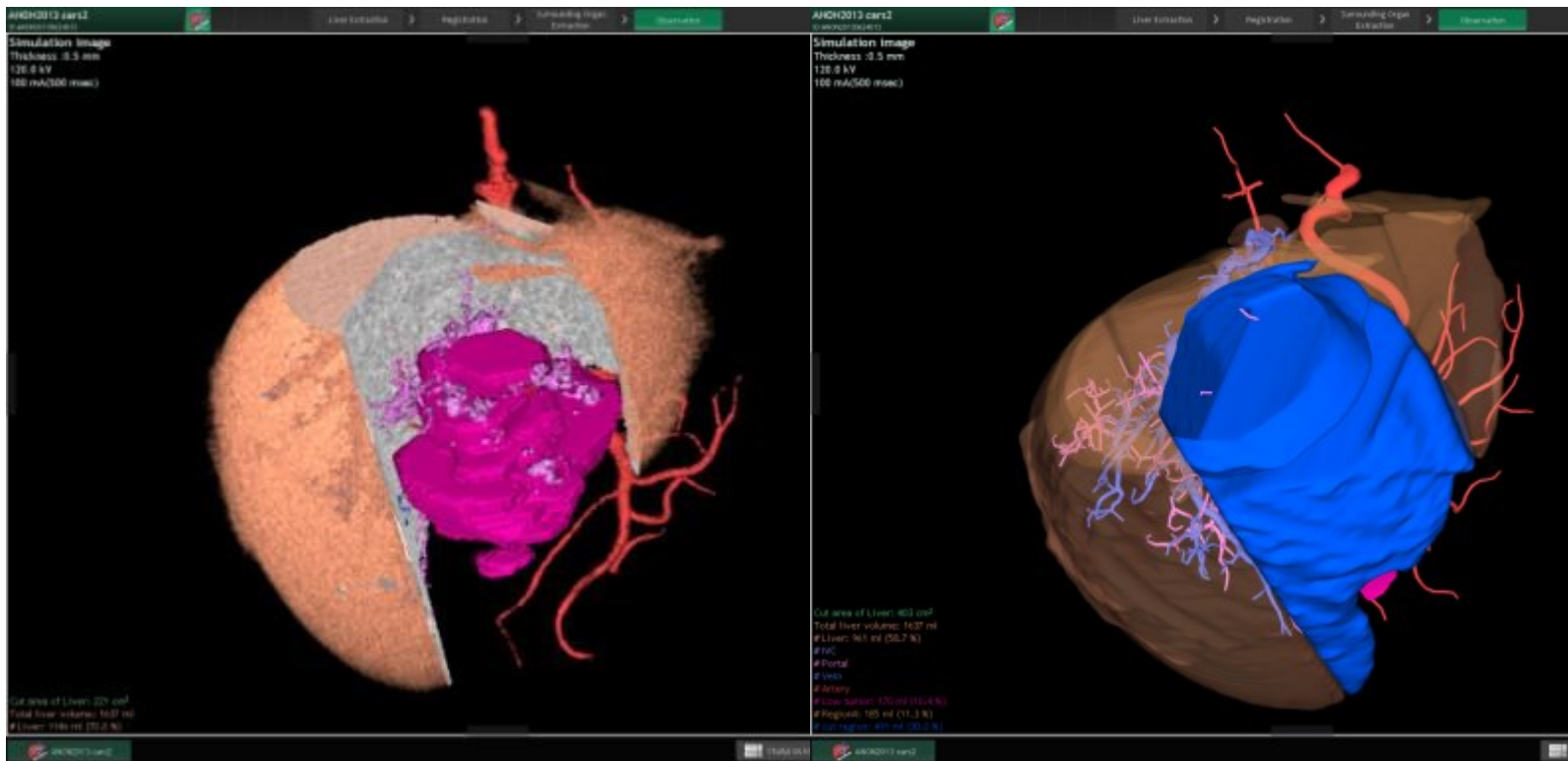
Cut Surface 33.3%



Surgical Planning

Case 2: **Low Tumor 10.4%**

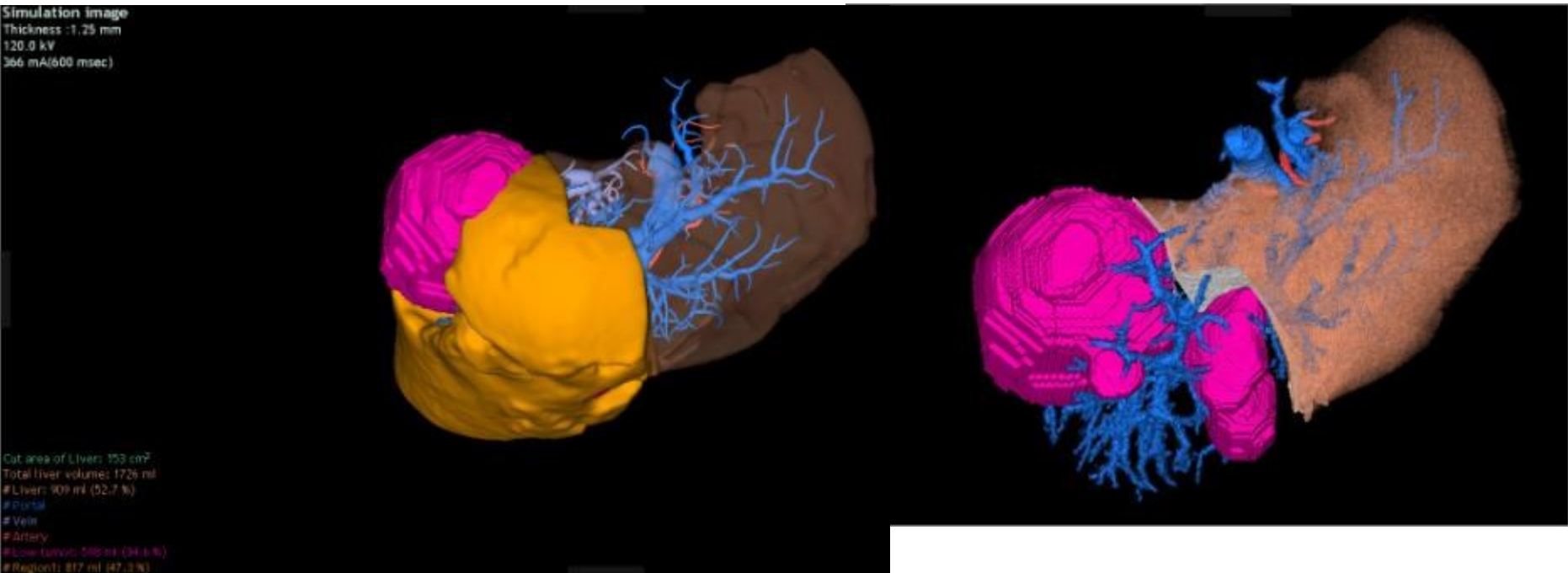
Cut Surface 30%



Surgical Planning

Case 3: **Low Tumor 34.6%**

Cut Surface 47.3%



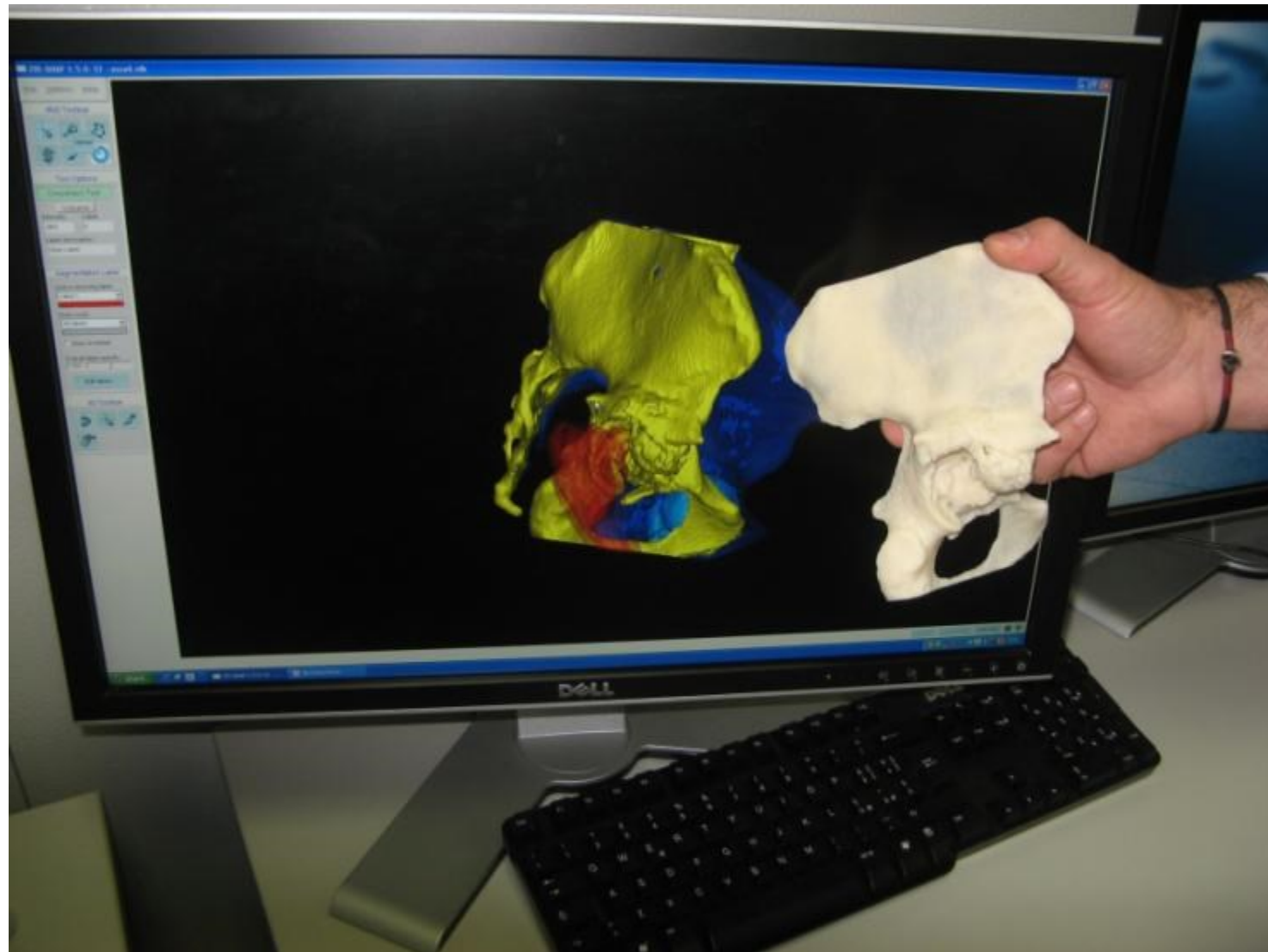
Total Liver: 1726ml

Liver: 909ml (52.7%)



REPLICHE FISICHE PAZIENTE SPECIFICHE....

Prototipazione rapida per uso clinico



Pianificazione chirurgica / Simulazione



Considerations on segmentation tools/protocol

Initialization	Input of arguments or parameters. Either from keyboard, mouse or other forms of input devices.
	Some pre-processing of image data to either enhance quality (sharpening or noise removal)
	Evaluation of the complexity of the image data to improve decision making during input of arguments/parameters.
	User selecting the object from the first slice of the data set to be processed or from a three-dimensional representation.
Intervention/ Feedback response	Steering of the process continuously or intermittently towards a desired result.
	Responding to feedback data from process.
	Stopping the process midway when undesired results are obtained to make corrections, and then resume the process.
Evaluation	Evaluating the final result of the process to determine if it is correct or satisfactory. If not satisfactory – necessary changes are made to the arguments or parameters and the process is repeated, make modifications to the results, or in some cases results are simply rejected.