Computer Assisted Hybrid Image Guided Minimally Invasive Surgery

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IRCAD-IHU R&D Director

University of Strasbourg, France

Presenter Disclosure Slide

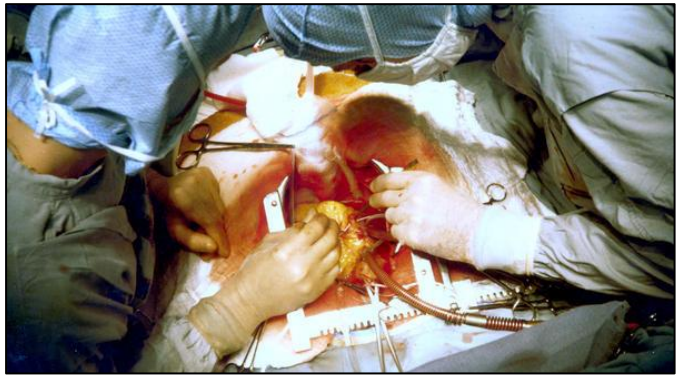
Luc Soler

A part of this work was cofunded by :

- *The European Commission: PASSPORT Project*
- *The French Minister of industry: ISIS Project*
- *The University-Hospital Institute (IHU) of Strasbourg*

*I am also cofounder and CEO of the **Visible Patient Company***

Evolution of Surgery like other Domains



before 1980

Large Incision

↓

1930-1940 :

Large Size

From 1980

Small Incision

↓

1946-1960 :

Smaller Size

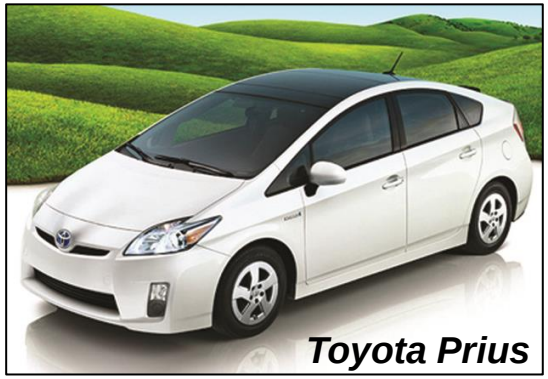
From 2000

Robotisation

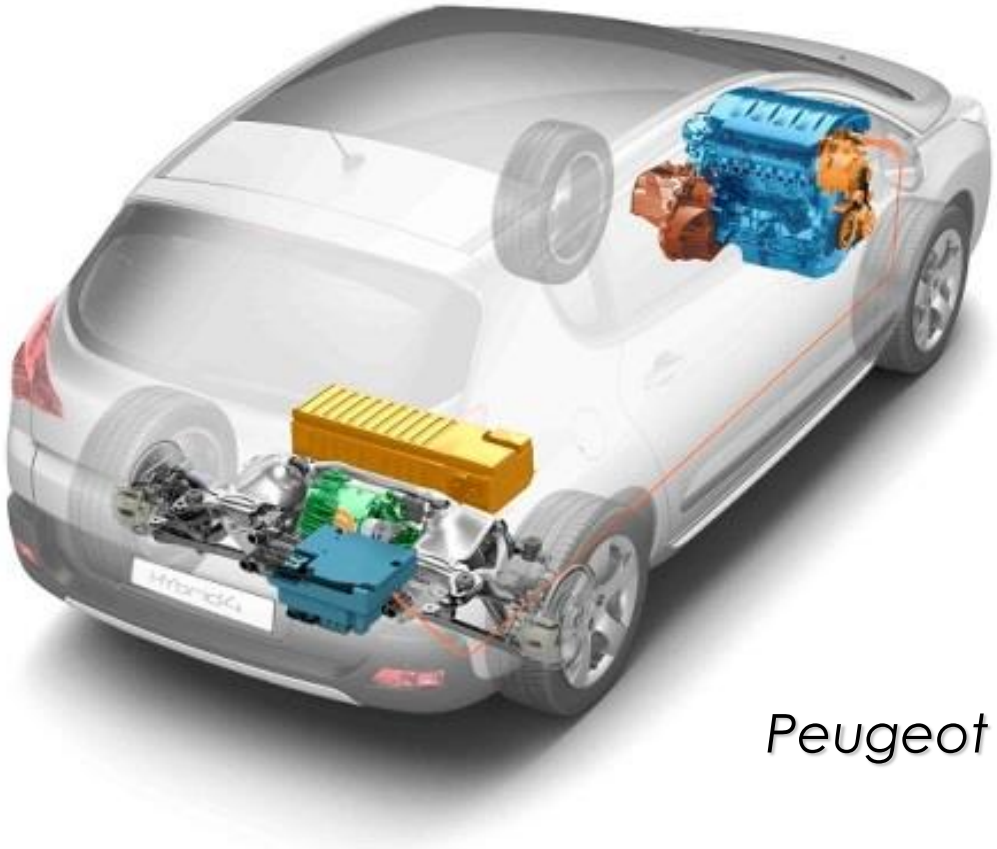
↓

Since 1980 :

Robotized



From Hybrid car to Hybrid Surgery



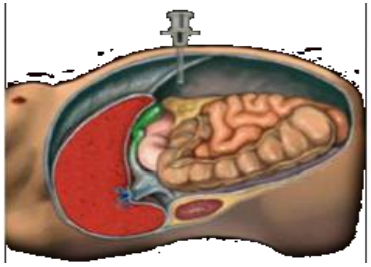
Peugeot hybride

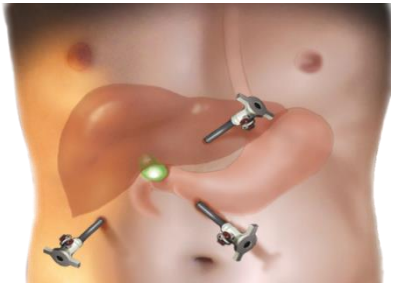
Something having two kinds of components that produce the same or similar results

What is Hybrid Surgery

Merging two (or more) Surgical techniques

Laparoscopic Surgery





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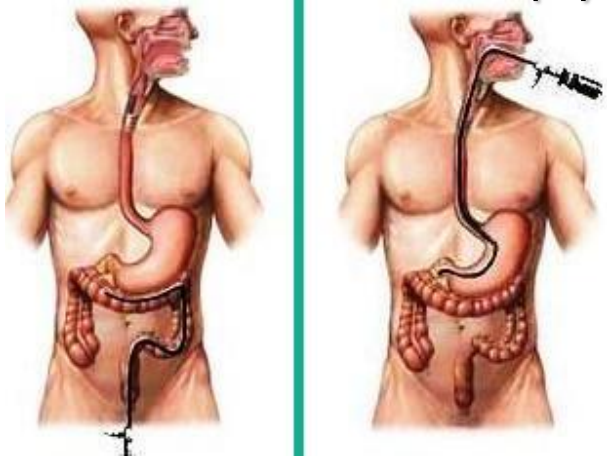
Flexible endoscopy



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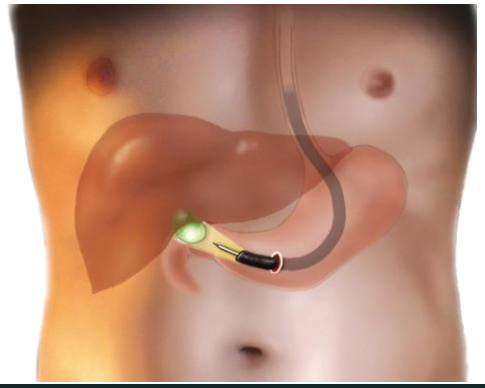
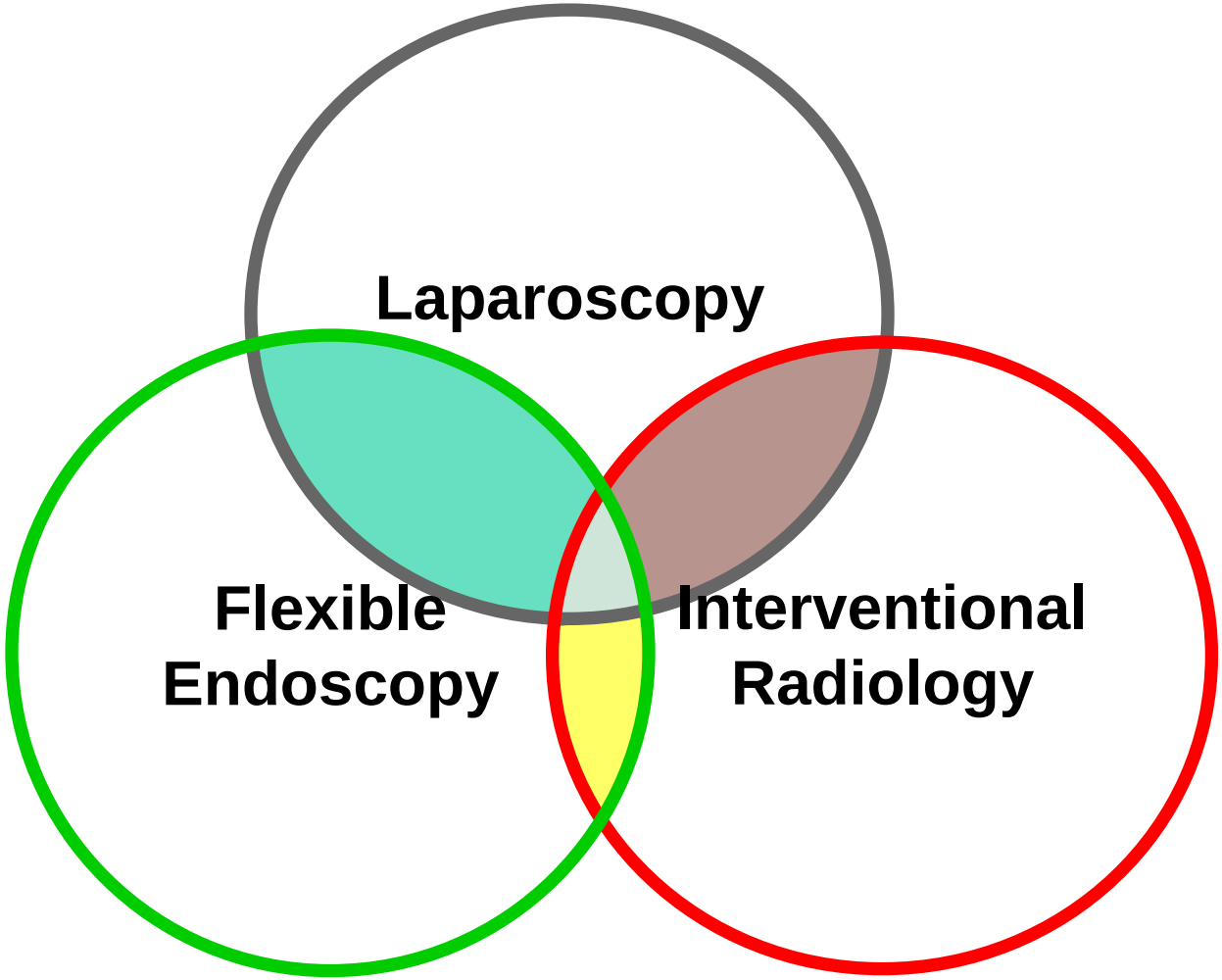


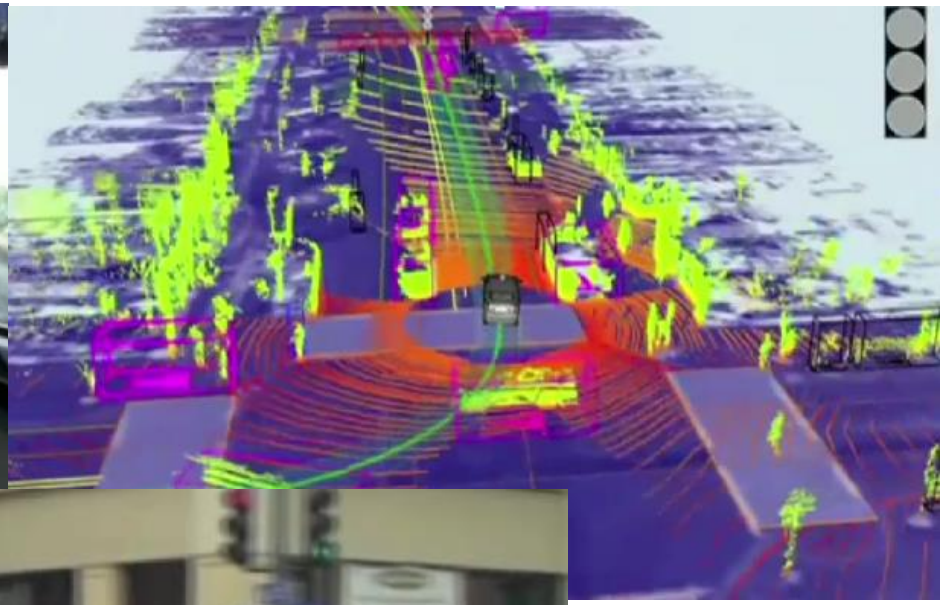
Natural Orifice Transluminal Endoscopic Surgery = NOTES

Hybride Minimally Invasive Surgery

Hybride Minimally Invasive Surgery

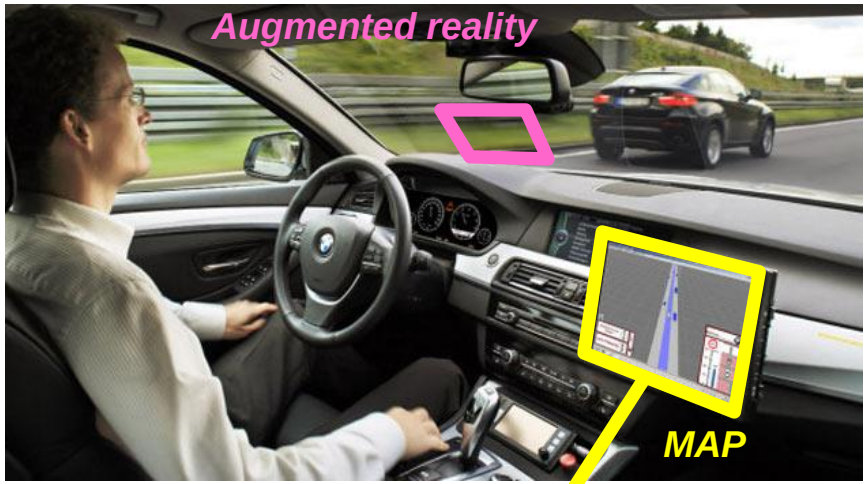


The future is automation (google car)

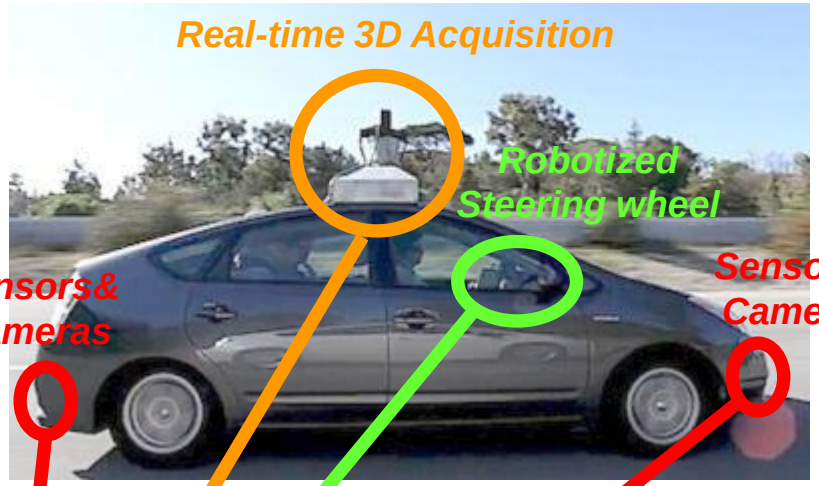


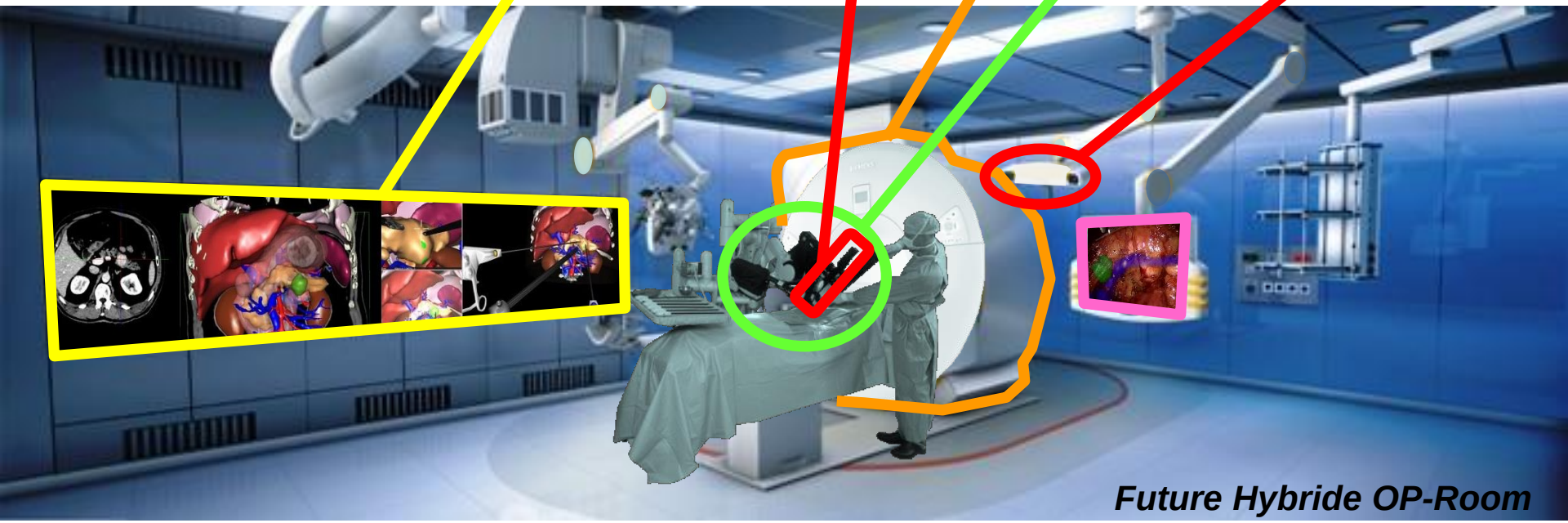
New Technologies can avoid Human errors !

Develop the same concept in surgery



Toyota Google Car

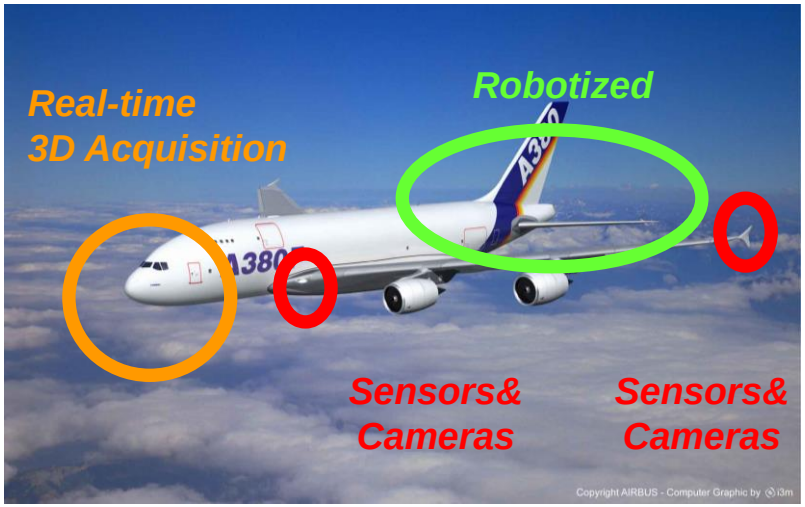


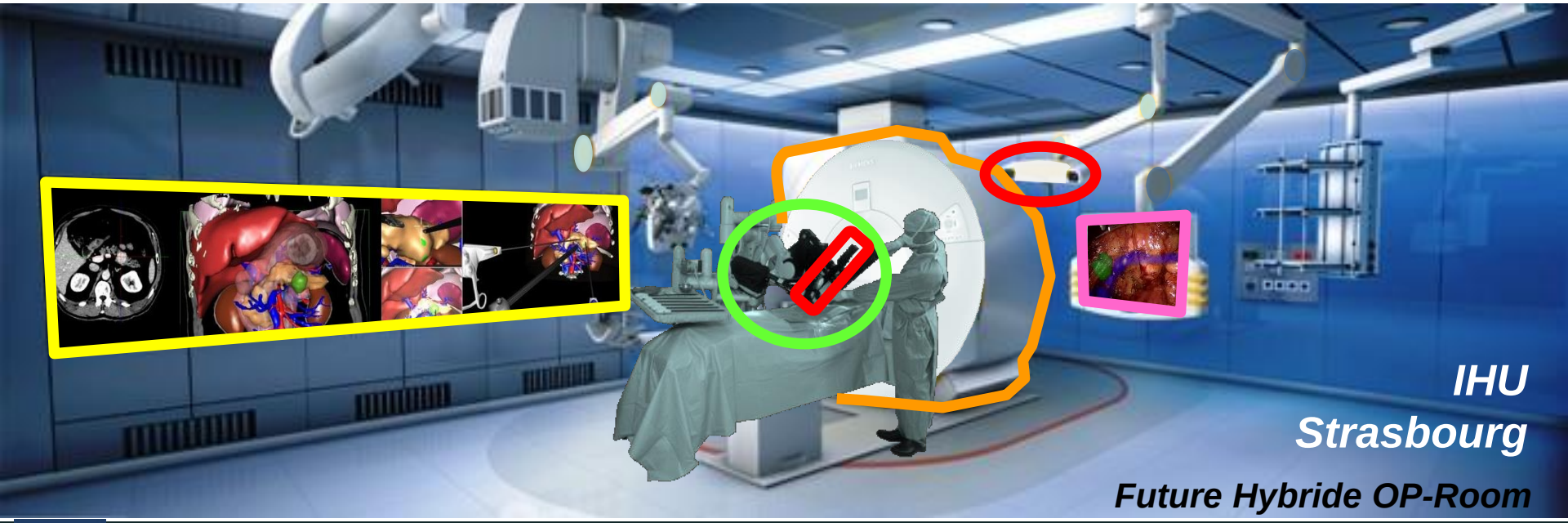


Future Hybride OP-Room

The same concept than aeronautic

Airbus A380





IHU – IRCAD : R&D Objectives

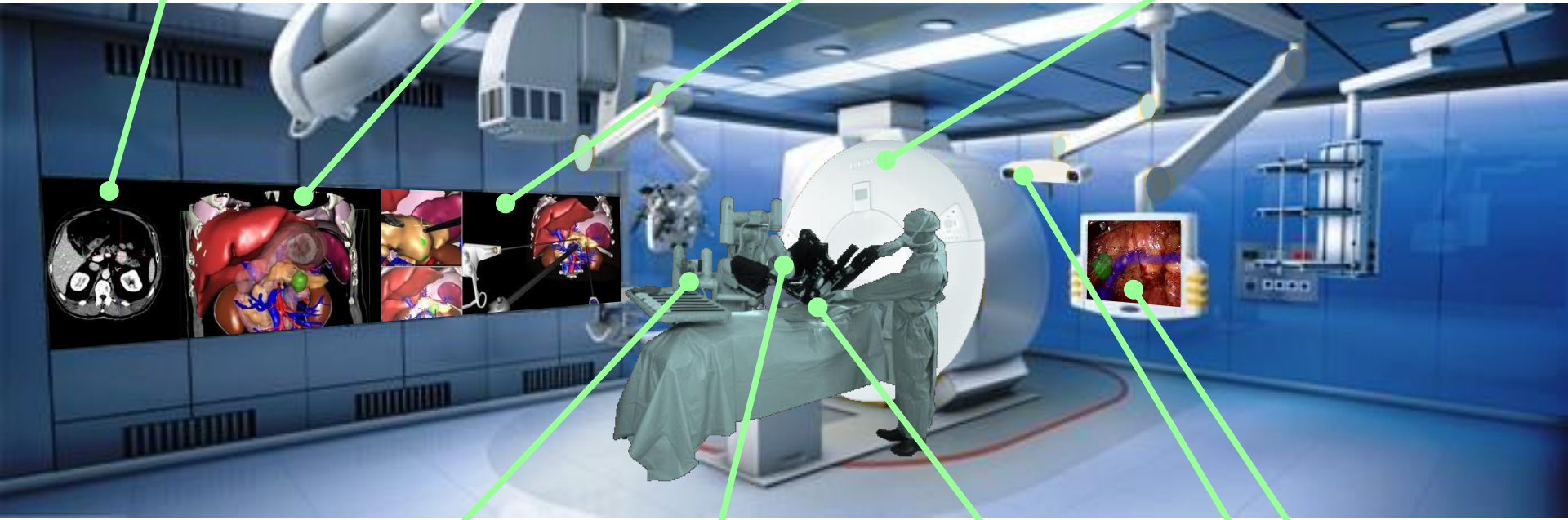
Databank : Digital & Biological Material

Pre-operative Medical Imaging

Digital Patient Modelling

Surgical Planning & Simulation

Intra-operative Medical Imaging



Education & Network

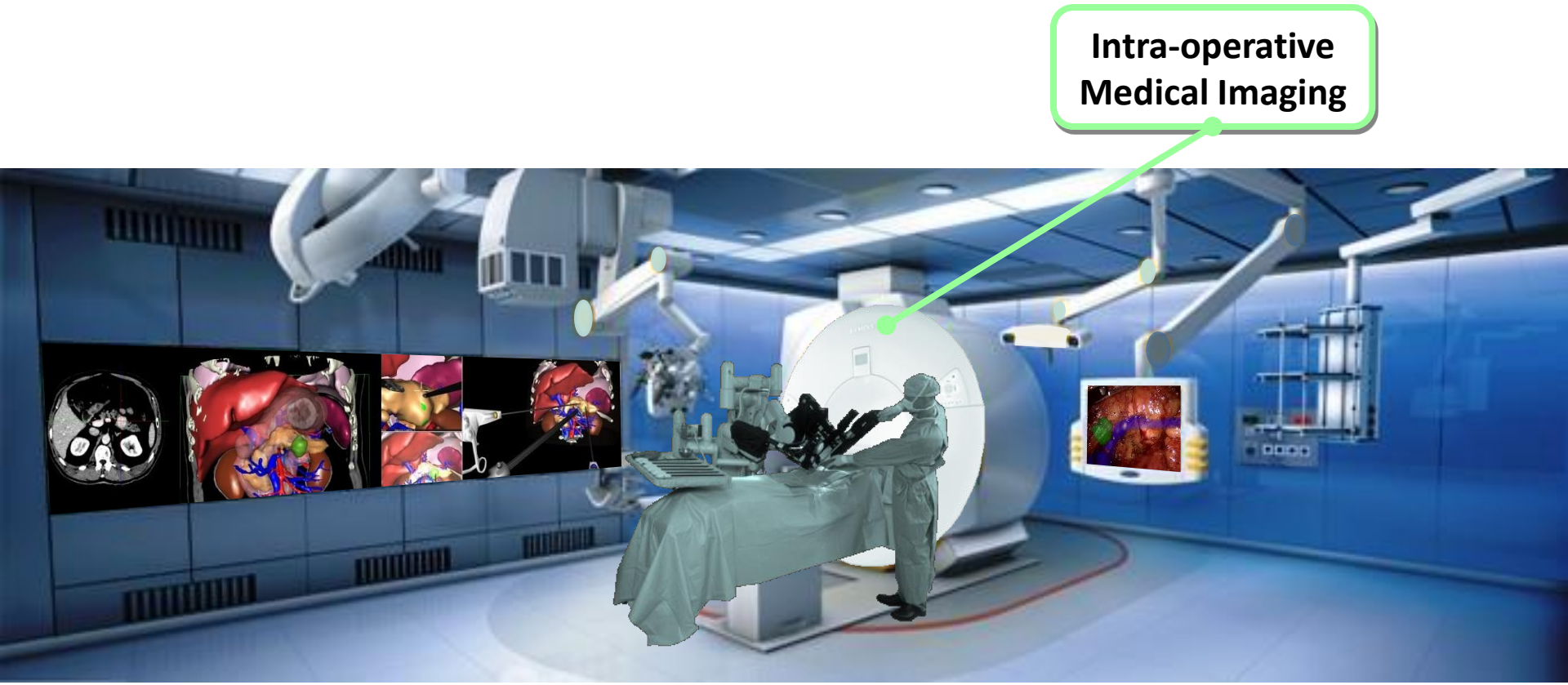
Biological Targetting

Robotics & Automation

New Surgical Devices

Tracking & Augmented reality

IHU – IRCAD : R&D Objectives



Another solution : Hybrid Room

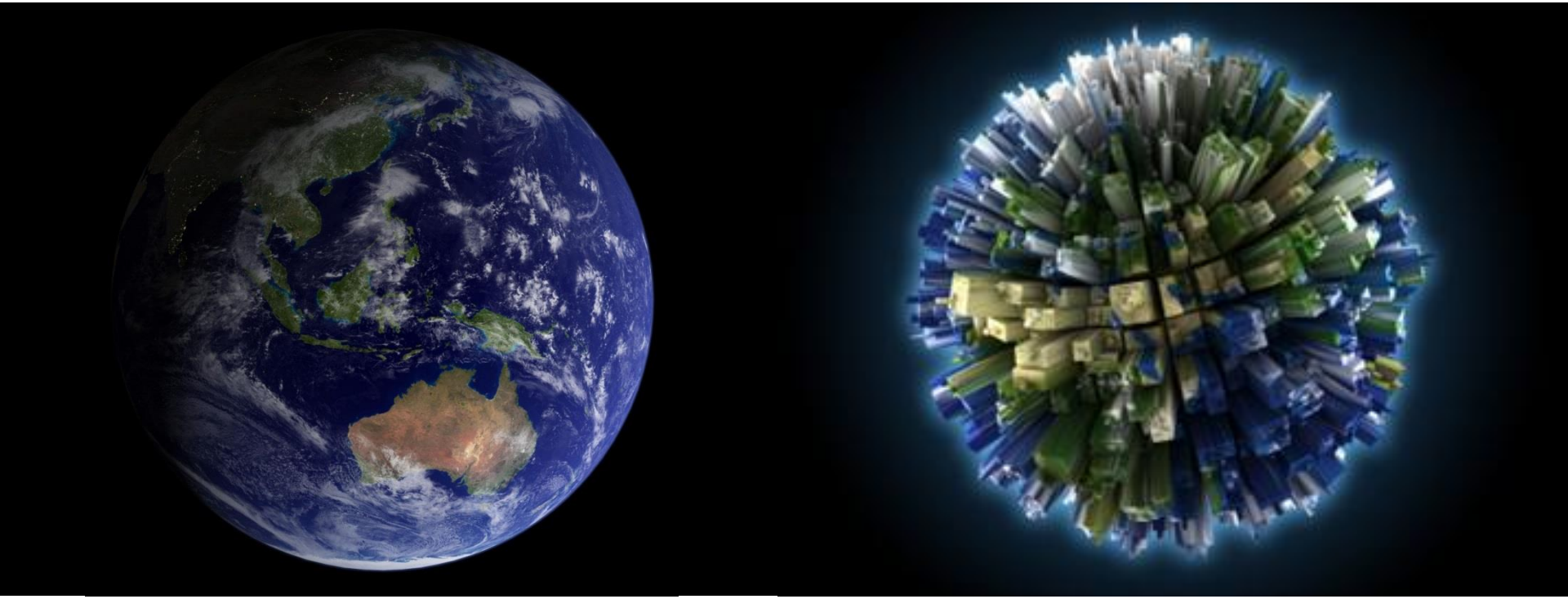
IHU – IRCAD : R&D Objectives

Pre-operative Medical Imaging

Digital Patient Modelling

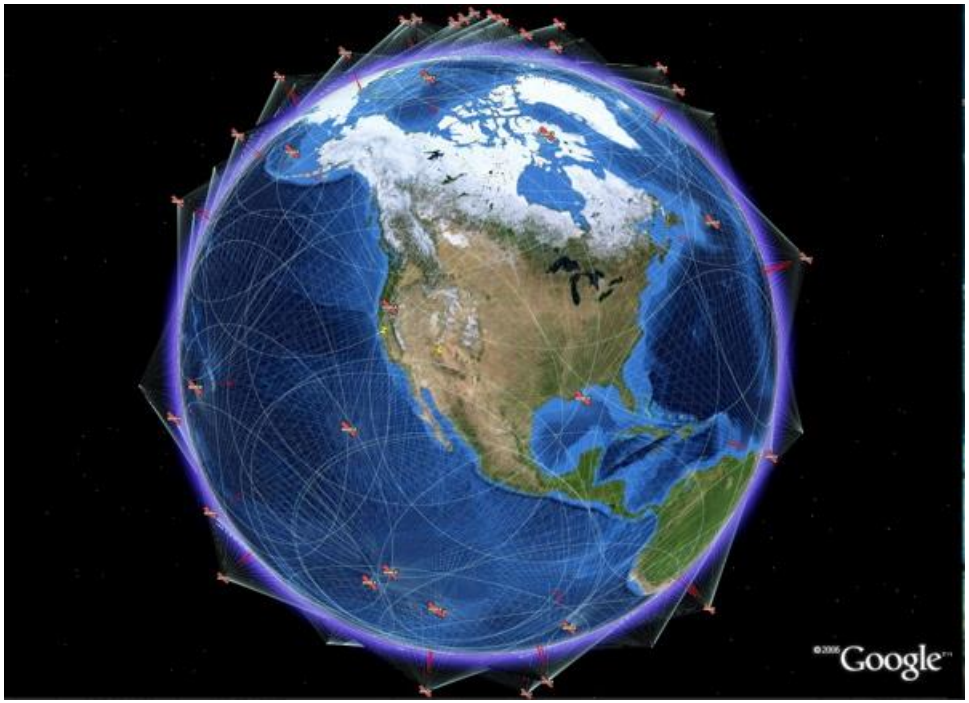
Surgical Planning & Simulation

1rst Element: The Patient Map



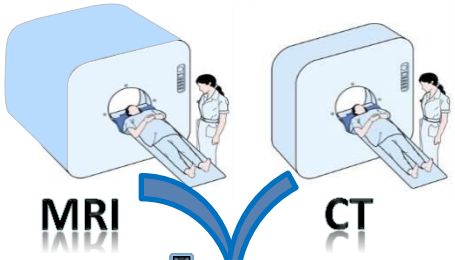
1Planet… but 7 Billions Humen

1rst Element: The Patient Map

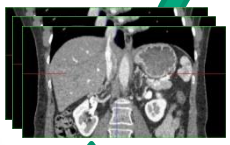


Satellite Views ➔Medical Images

The “Visible Patient” Service



ANONYMOUS

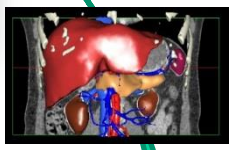


http://

Surgeon send
the DICOM images

VISIBLE PATIENT

VR-Med
© ircad 2010



http://

He downloads
the 3D model and
planes the surgery

VR-Planning
© ircad 2010

And then
He use it
in the OR

AR-Surg
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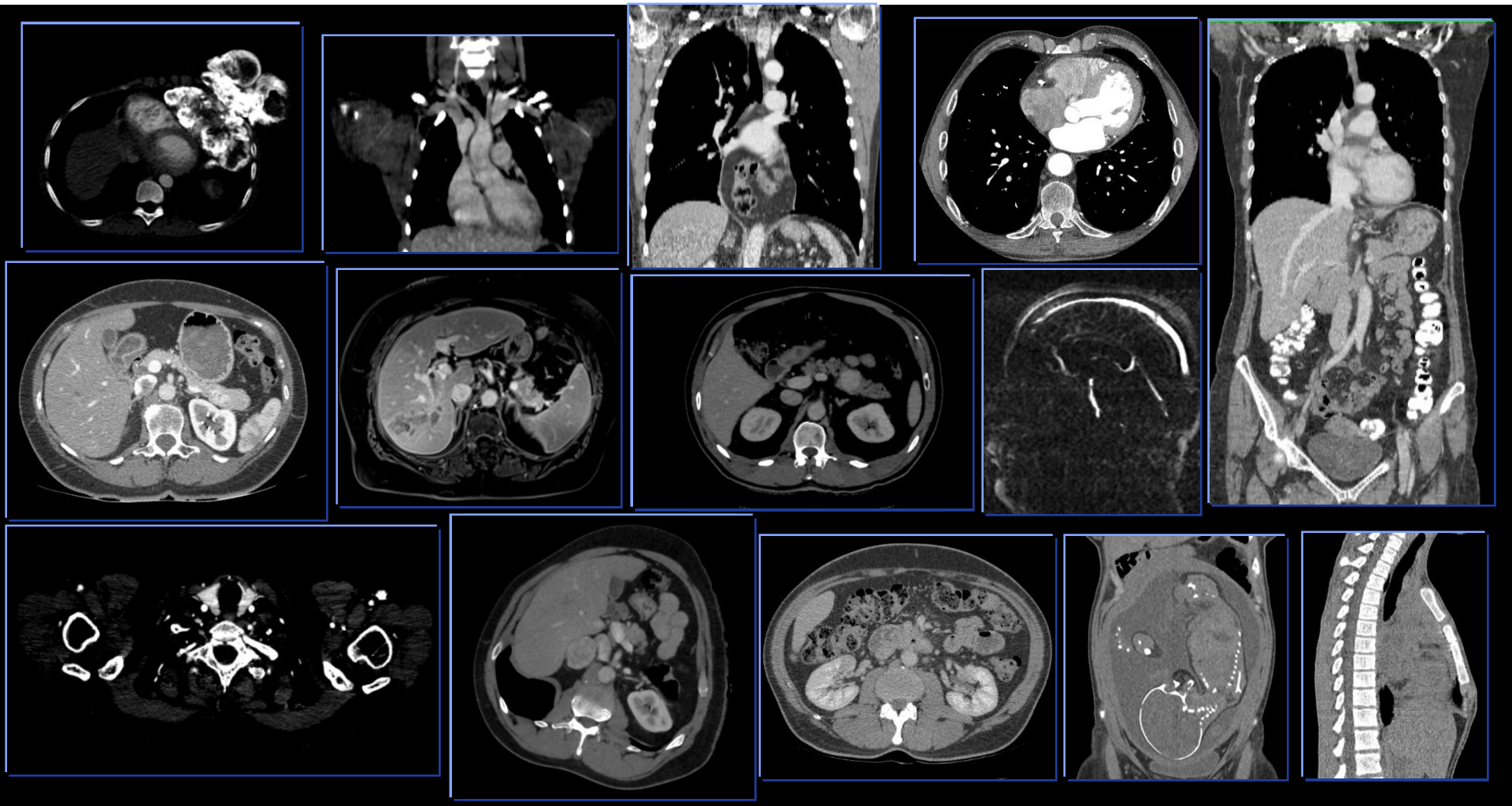
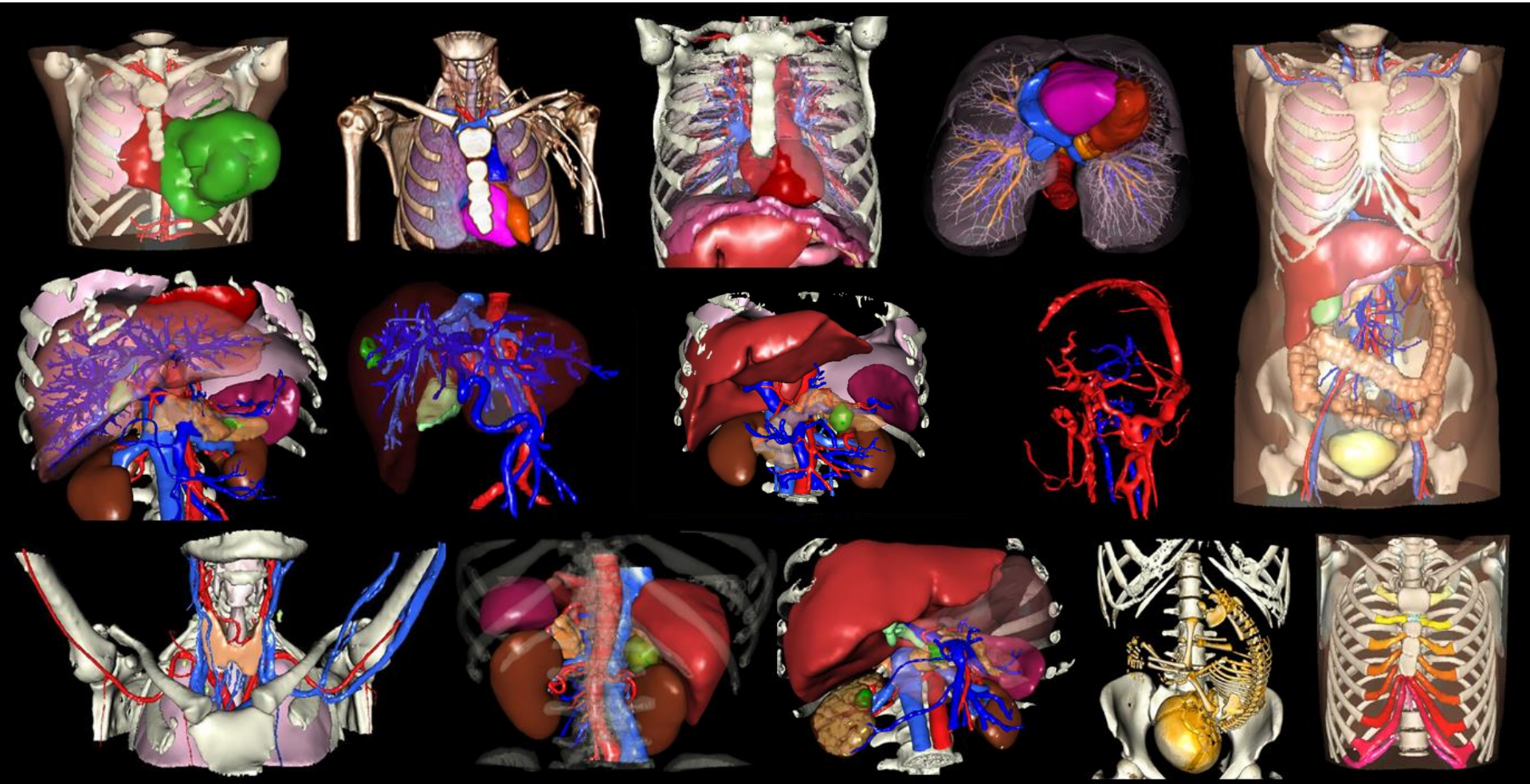
The Virtual image of the patient



VR-Med © ircad 2010

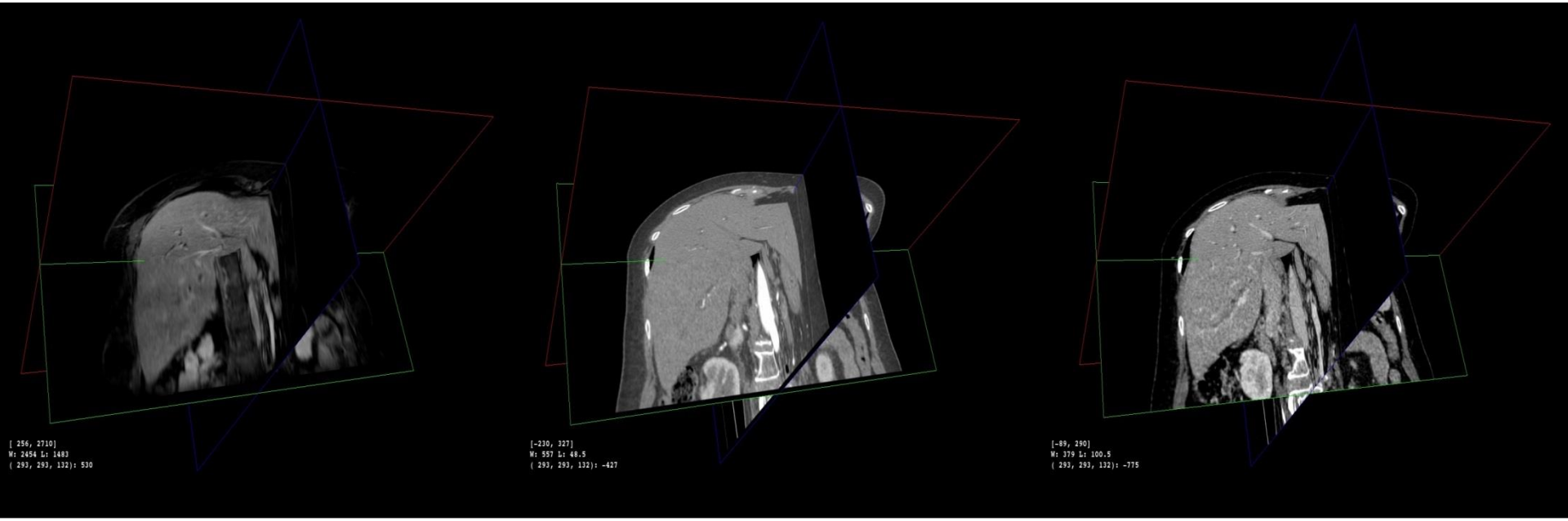
The Virtual image of the patient

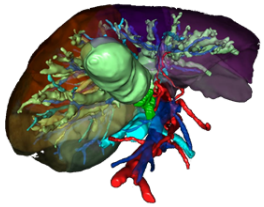


VR-Med © ircad 2010

Multimodality

MRI 3D images CT Arterial Phase CT Venous Phase

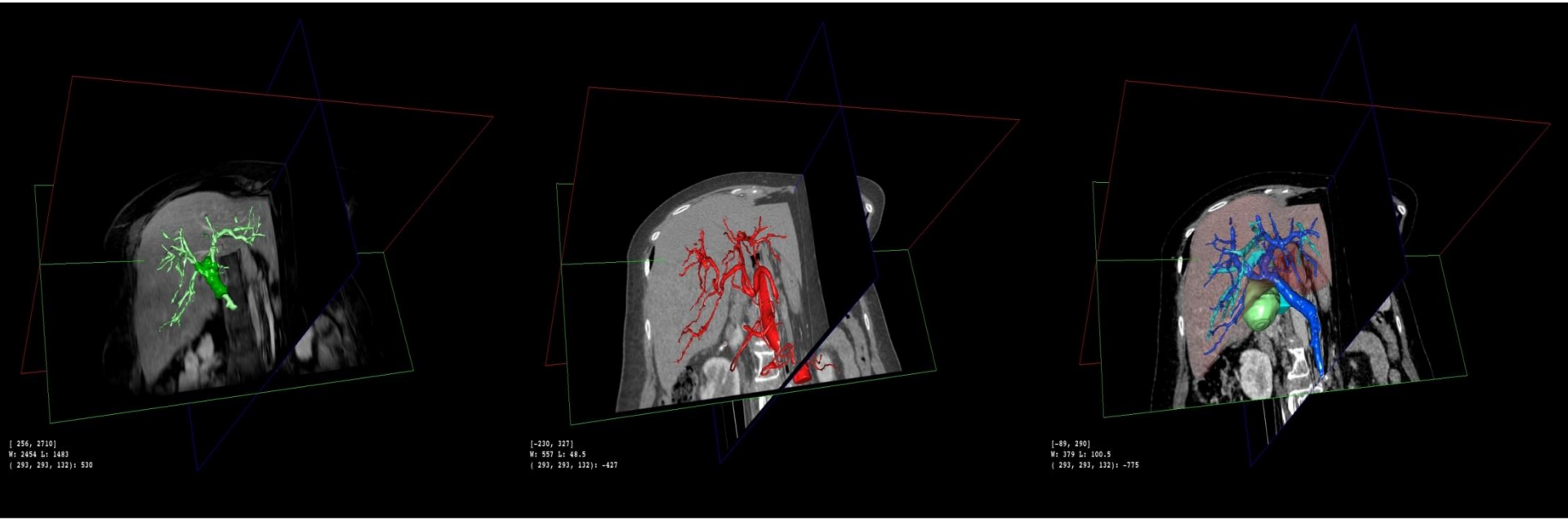


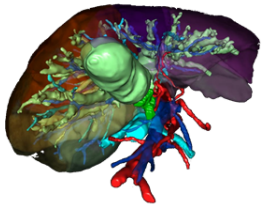


Visible Patient

Multimodality Modelling

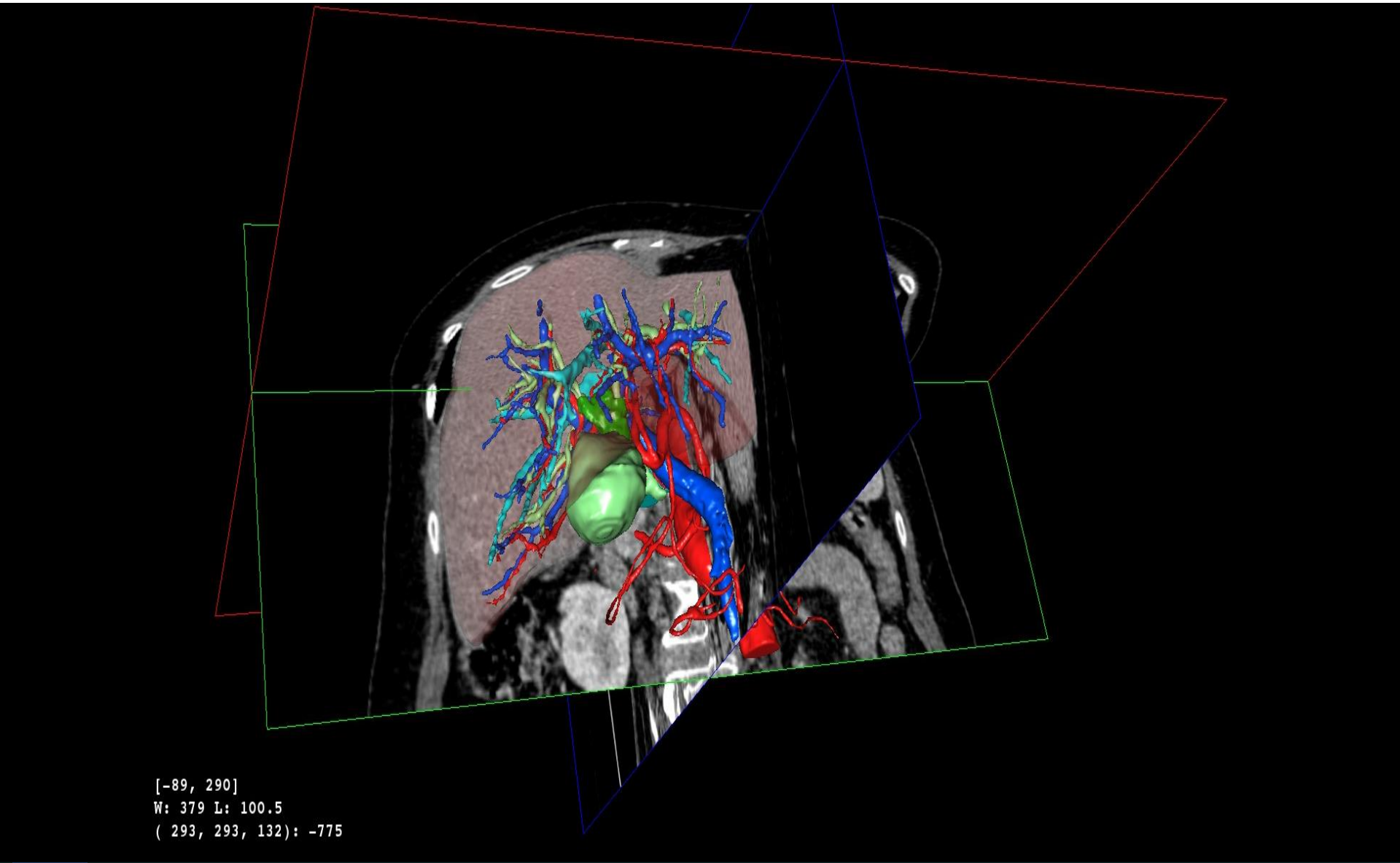
MRI 3D images CT Arterial Phase CT Venous Phase





Visible Patient

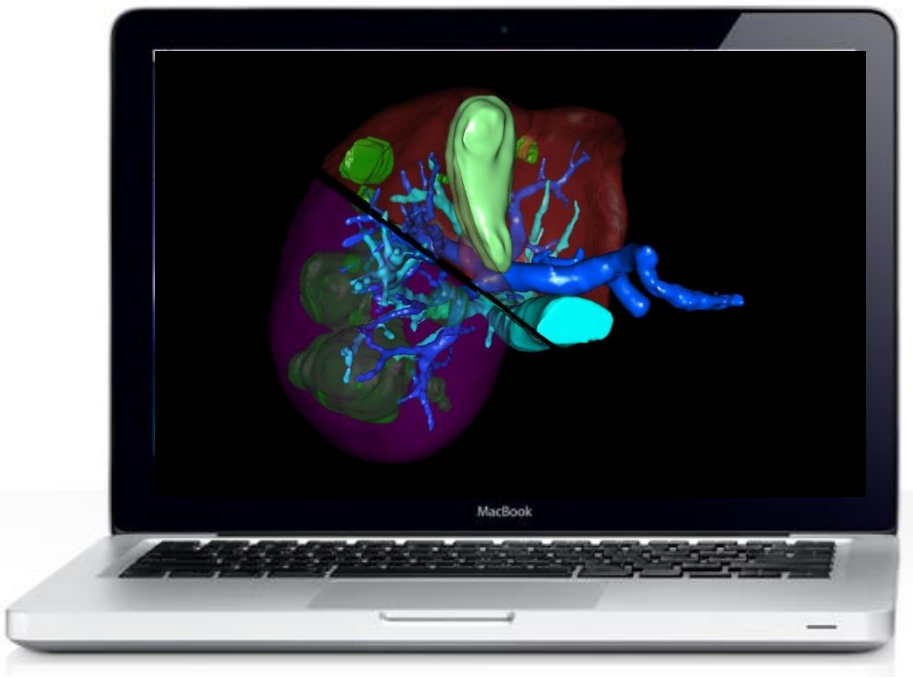
Multimodality Modelling & Registration



Intra operative registration

IHU Strasbourg R&D Platform

IRCAD Visualization software: FREE !!!



VR-Render © ircad 2010

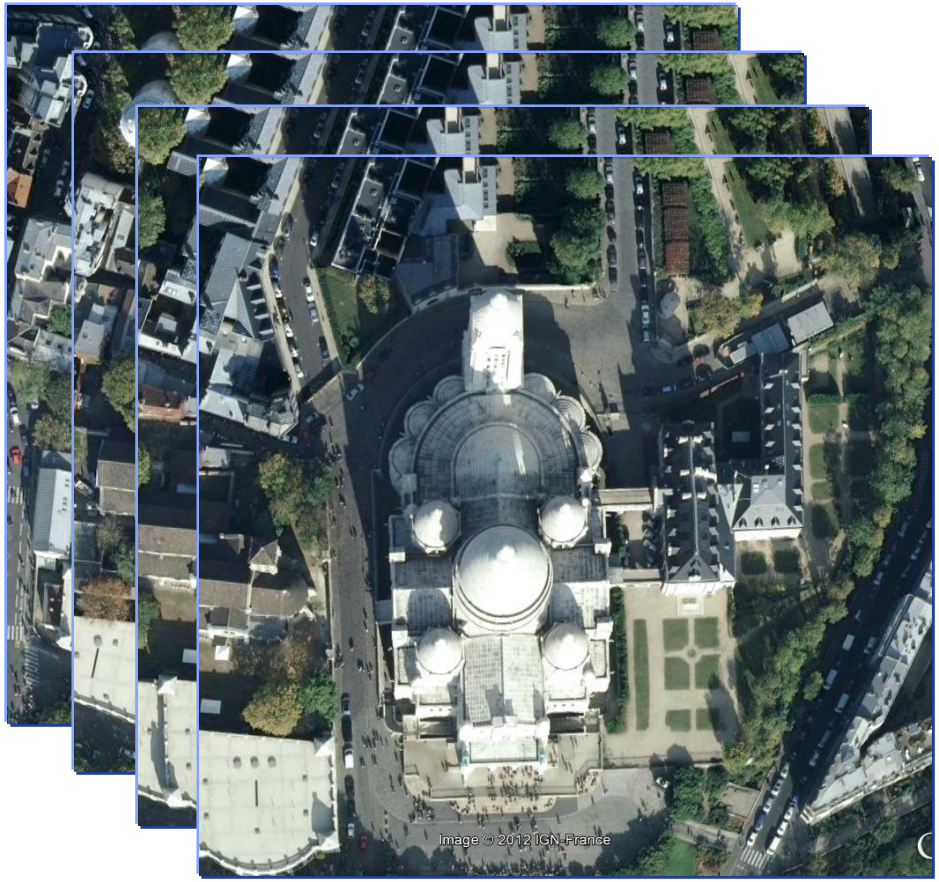
www.websurg.com/softwares
>13.000 users

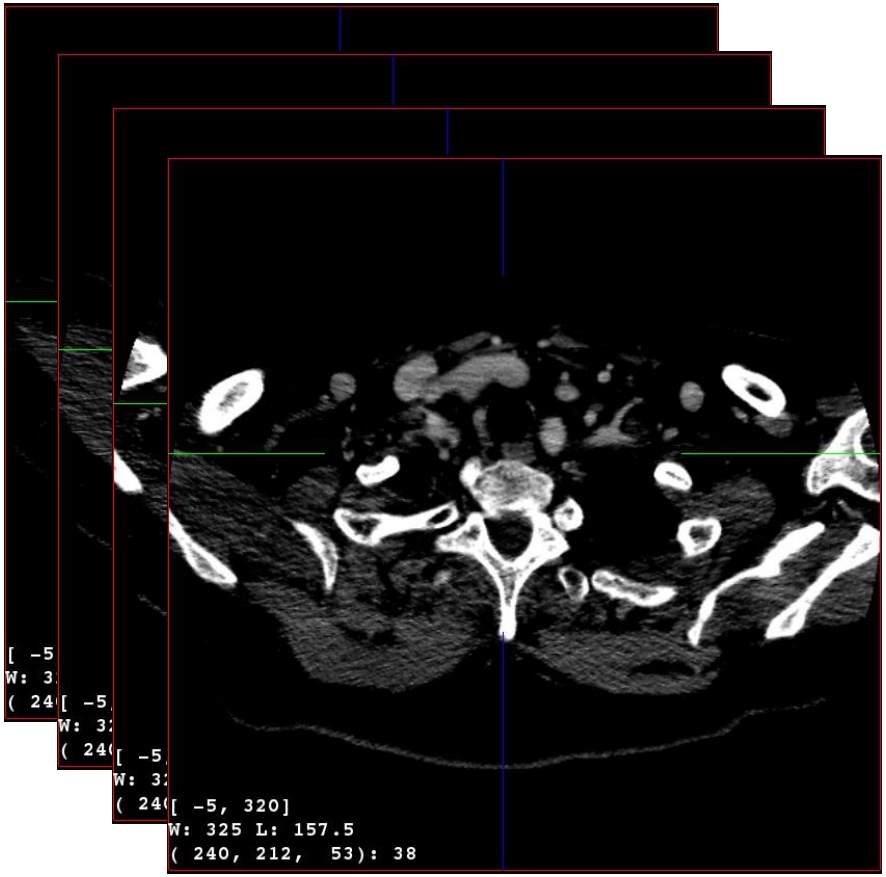
VR-Planning © ircad 2010

MultiOS system
Windows / MacOS / Linux

The patient MAP

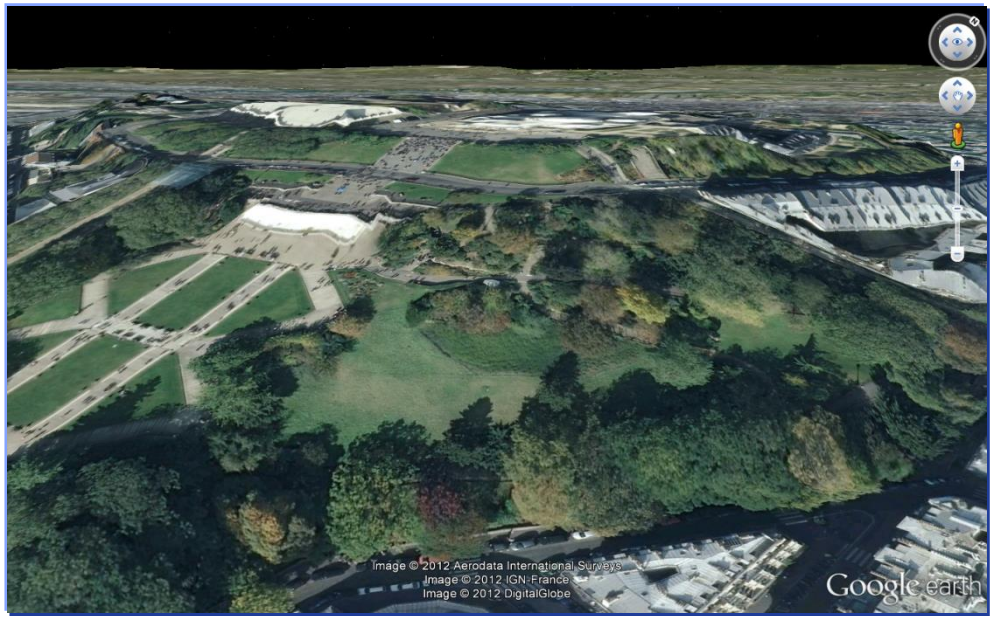
The satellite view ≈ medical image

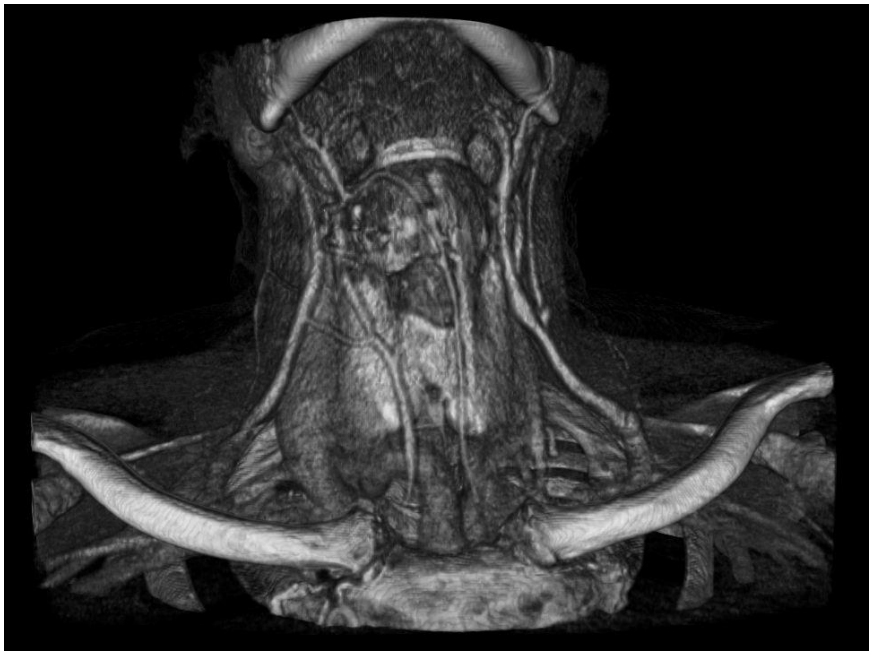




MAP

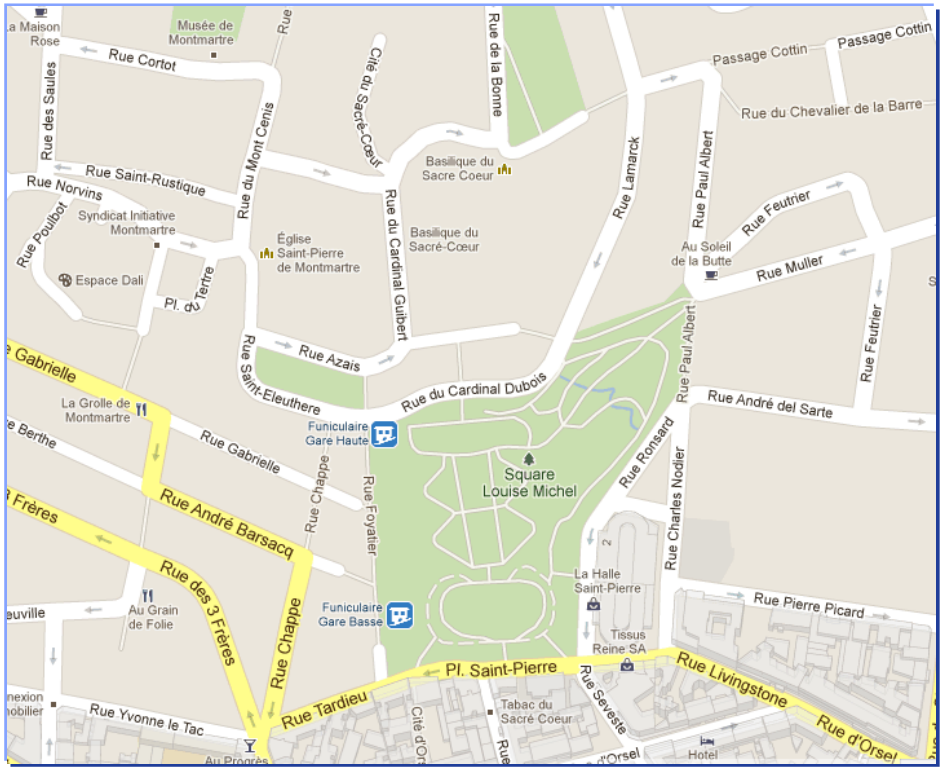
3D satellite view ≈ Volume rendering





MAP

Map ≈ Image segmentation



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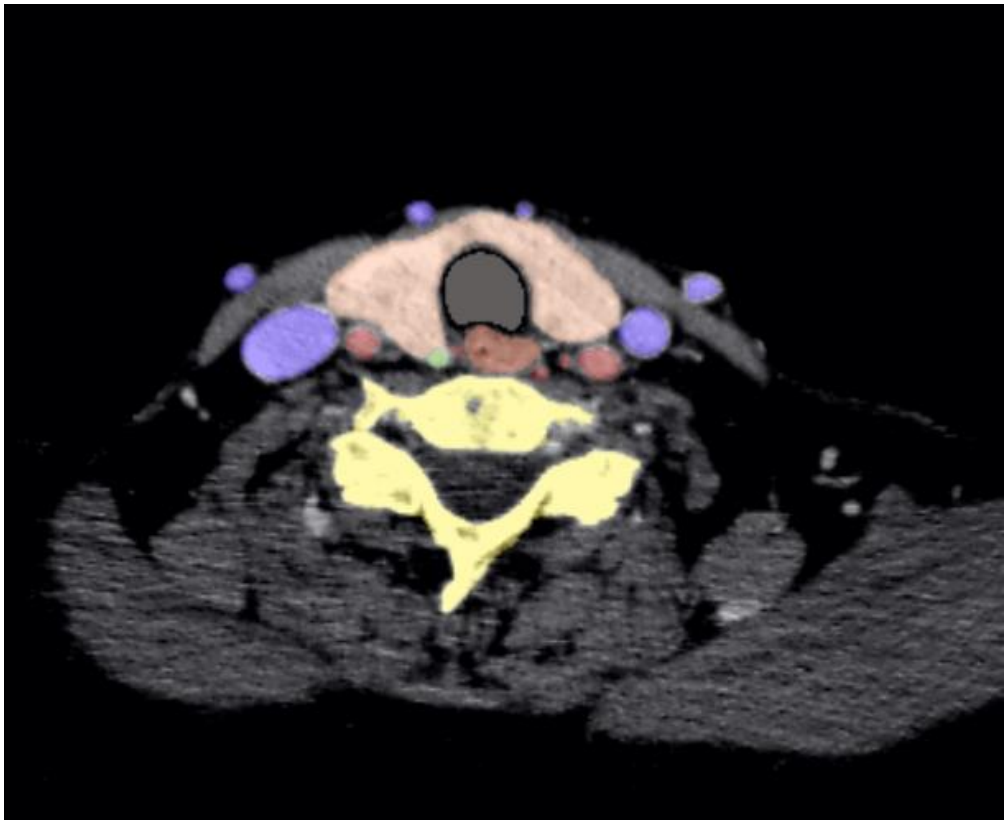
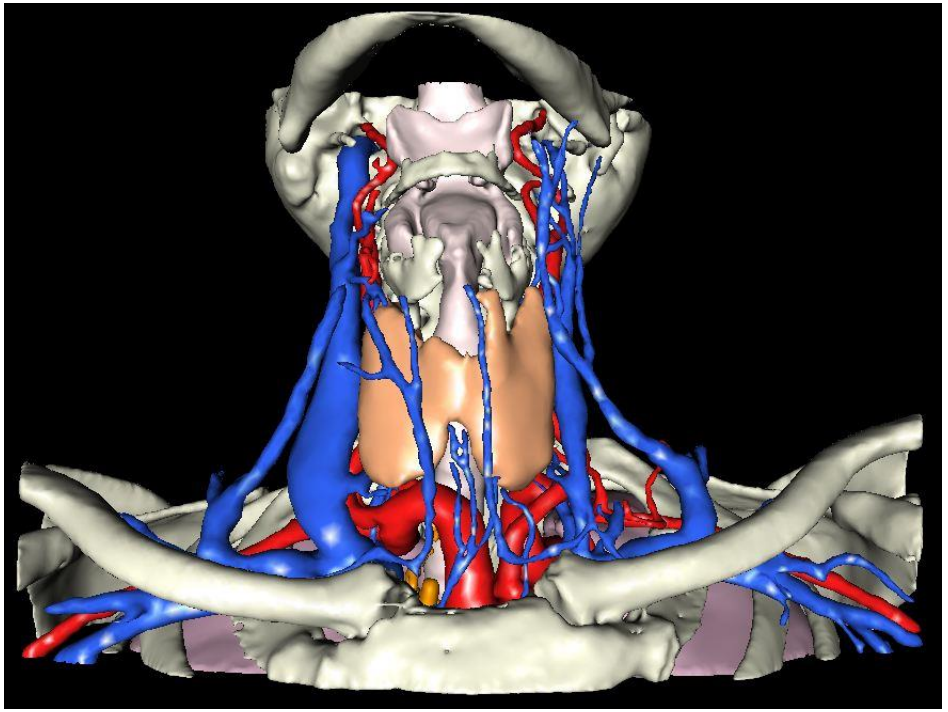


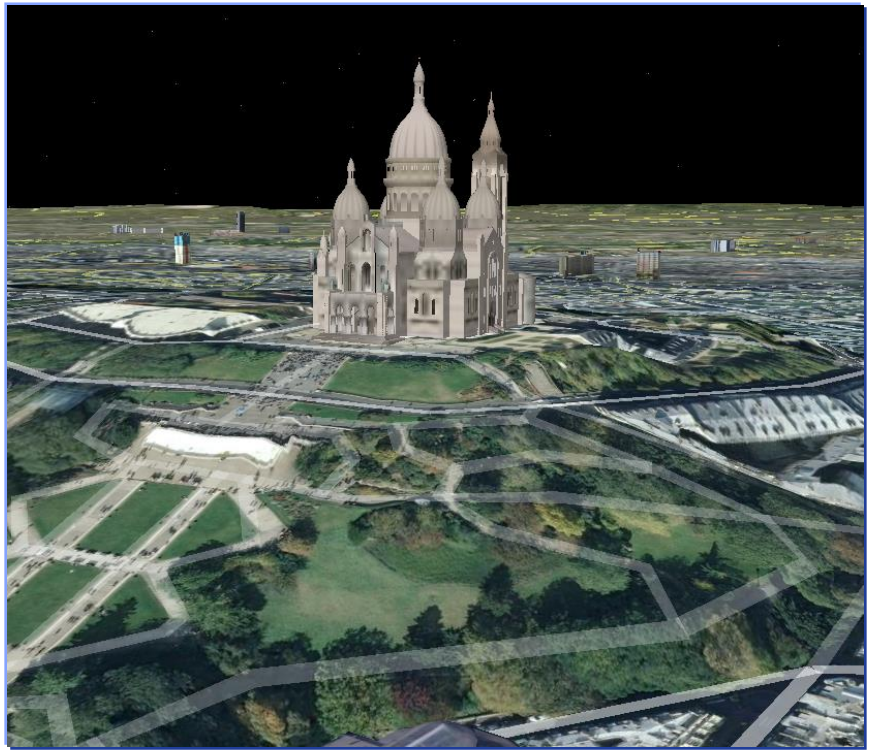
MAP

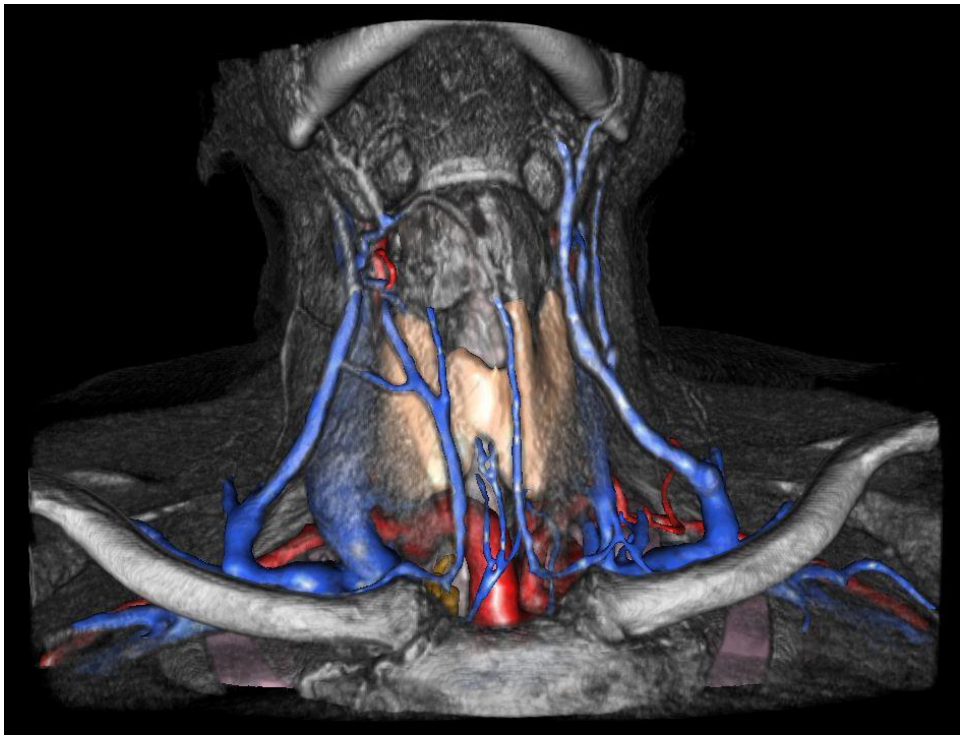
3D view ≈ 3D Models



MAP

Satellite + Map = VR + 3D models





Clinical Validation

Benefit of 3D planification to the surgical resection of liver tumors

Prof. Jean-Jacques Houben, Dr. Thierry Ballet, Dr. Roland Fastrez
Cavell Department of Digestive Surgery

Clinical Validation

Aim : establish the benefit of preoperative liver reconstruction for Radiofrequency Ablation, Liver Resection and Liver Regeneration

17 patients selected among 48 liver tumors

Criteria of selection :
Resection seems not possible or highly complex

Clinical Validation : Results

Requested modelling : 35% of cases

Impact : 27% (76%) of cases

13 procedures modified from initial planning thanks to Virtual modelling and planning.

Proof benefit : 20% (59%) of cases

10 with high benefit for safe hepatectomy, confirmed by postoperative Petscan, CEA drop and clinical outcome.

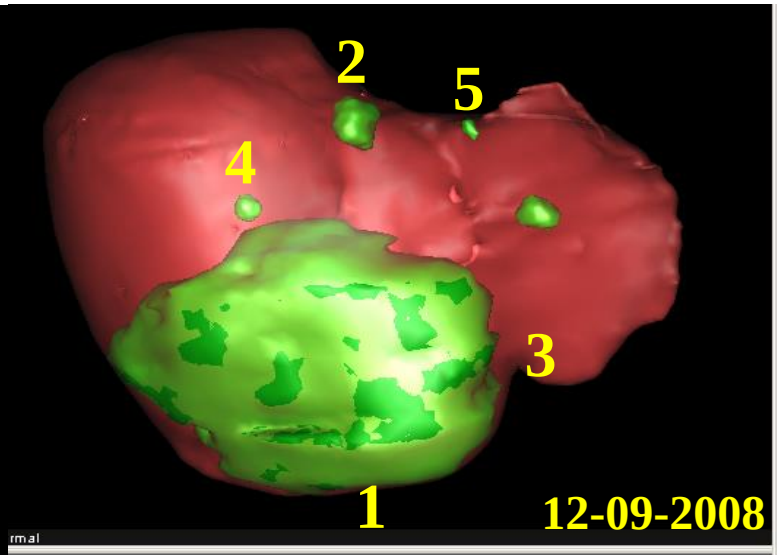
Usual Tumor follow Up : RECIST

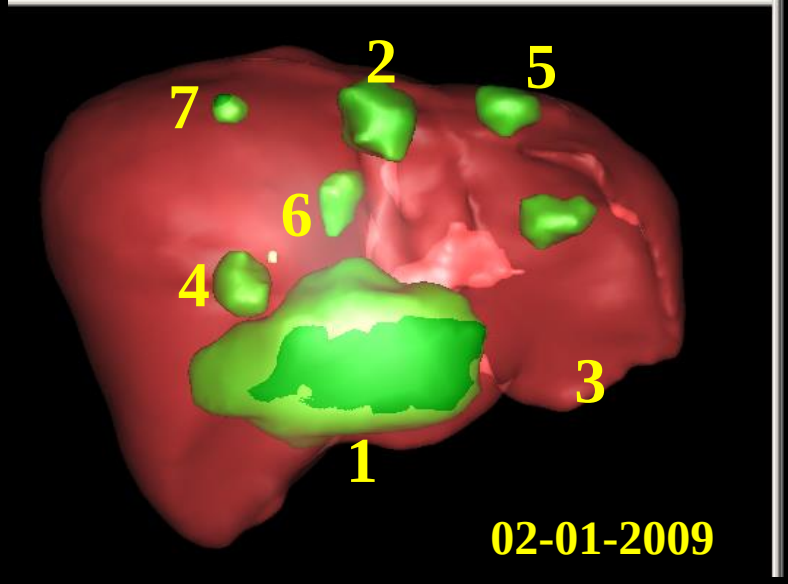
ONLY 1D + t

RECIST 1.1	Baseline	Followup 1	Followup 2	Followup 3
	2010-05-05 17:46:22 +0200	2010-07-13 13:47:04 +0200	2010-09-01 12:37:47 +0200	2010-10-21 12:24:01 +0200
RECIST absolut	119.51 mm	86.18 mm	83.44 mm	100.91 mm
Difference to Baseline in %	---	-27.89	-30.18	-15.56
Target Lesion 1	59.31 mm	45.51 mm	42.30 mm	46.63 mm
Target Lesion 2	14.41 mm	13.73 mm	11.61 mm	13.27 mm
Target Lesion 3	27.63 mm	17.27 mm	22.77 mm	36.21 mm
Target Lesion 4	18.16 mm	9.68 mm	6.77 mm	4.80 mm
Non-Target Lesion 1				28.28 mm
Non-Target Lesion 2				28.84 mm

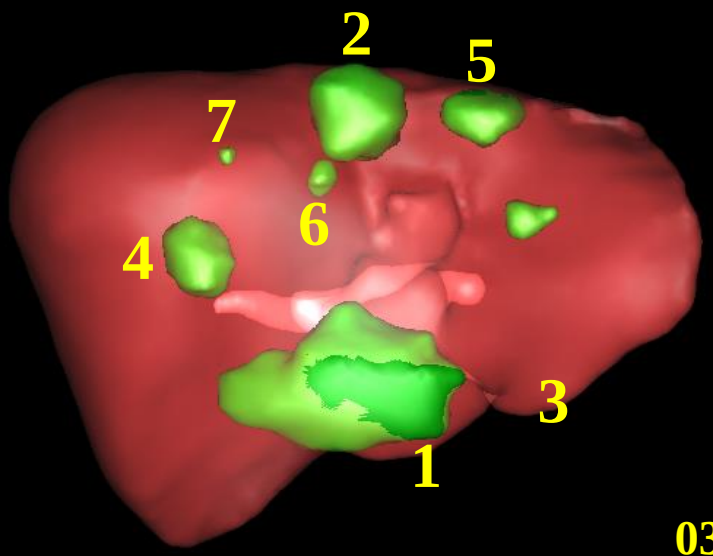
aycan
PACS for People

4D :Planning from 3D patient map

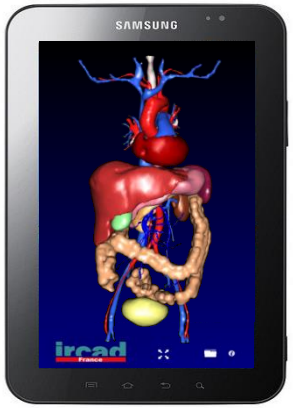




Volumes en cc	12/09/2008	02/01/2009	03/04/2009	Evolution
Tumeur 1	420,00	82,60	41,00	↘ ↘
Tumeur 2	2,90	9,80	14,80	↗ ↗
Tumeur 3	1,10	3,50	1,12	↗ ↘
Tumeur 4	0,80	7,20	7,20	↗ →
Tumeur 5	0,10	2,60	4,10	↗ ↗
Tumeur 6	0,00	2,40	0,53	↗ ↘
Tumeur 7	0,00	0,30	0,08	↗ ↘
Total	424,90	108,40	68,83	↘ ↘



IRCAD Visualization software: FREE !!!

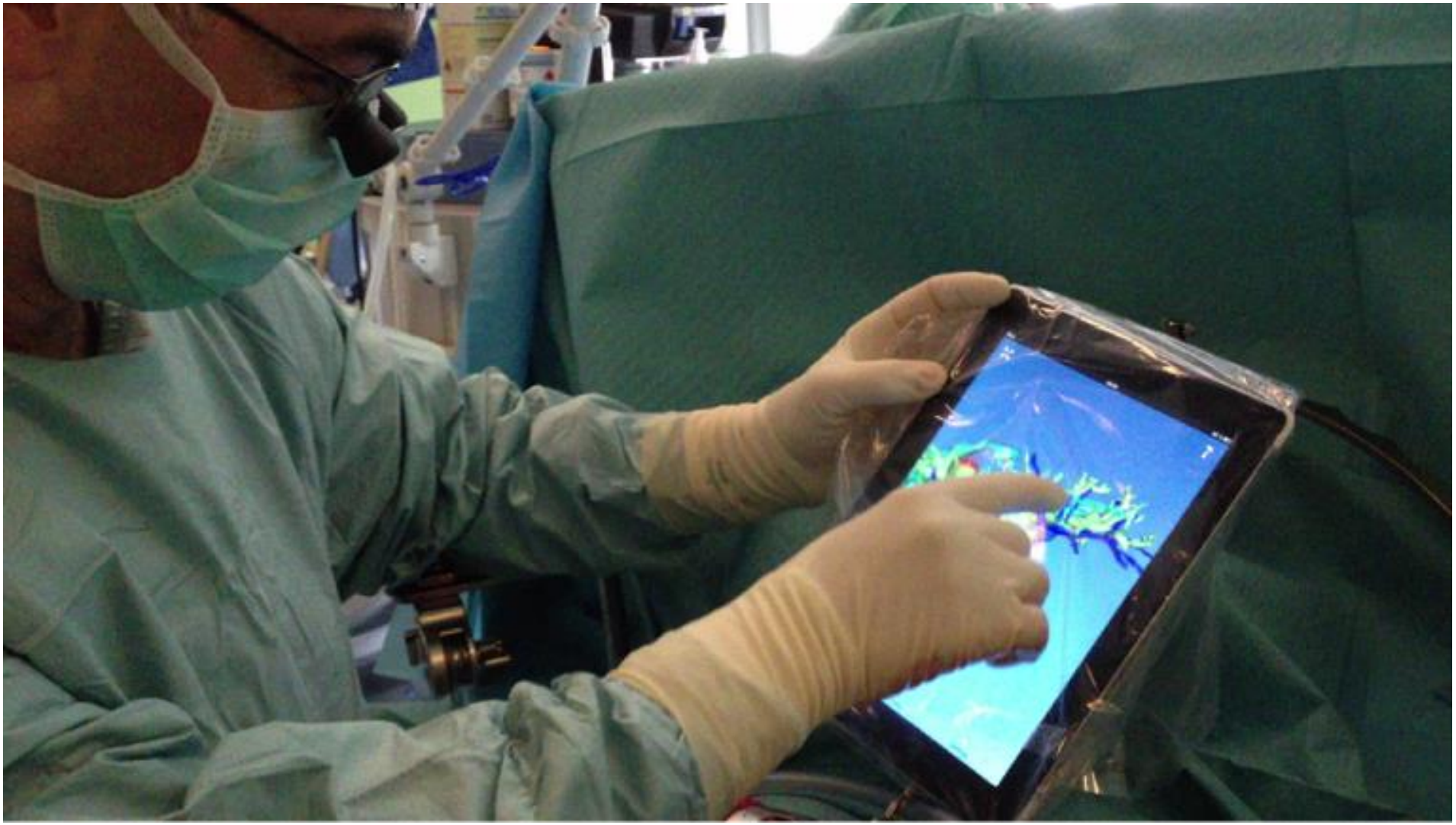


Visible Patient

Kitware ircad France

Mobile GPS → *www.visiblepatient.eu*
> 60.000 users

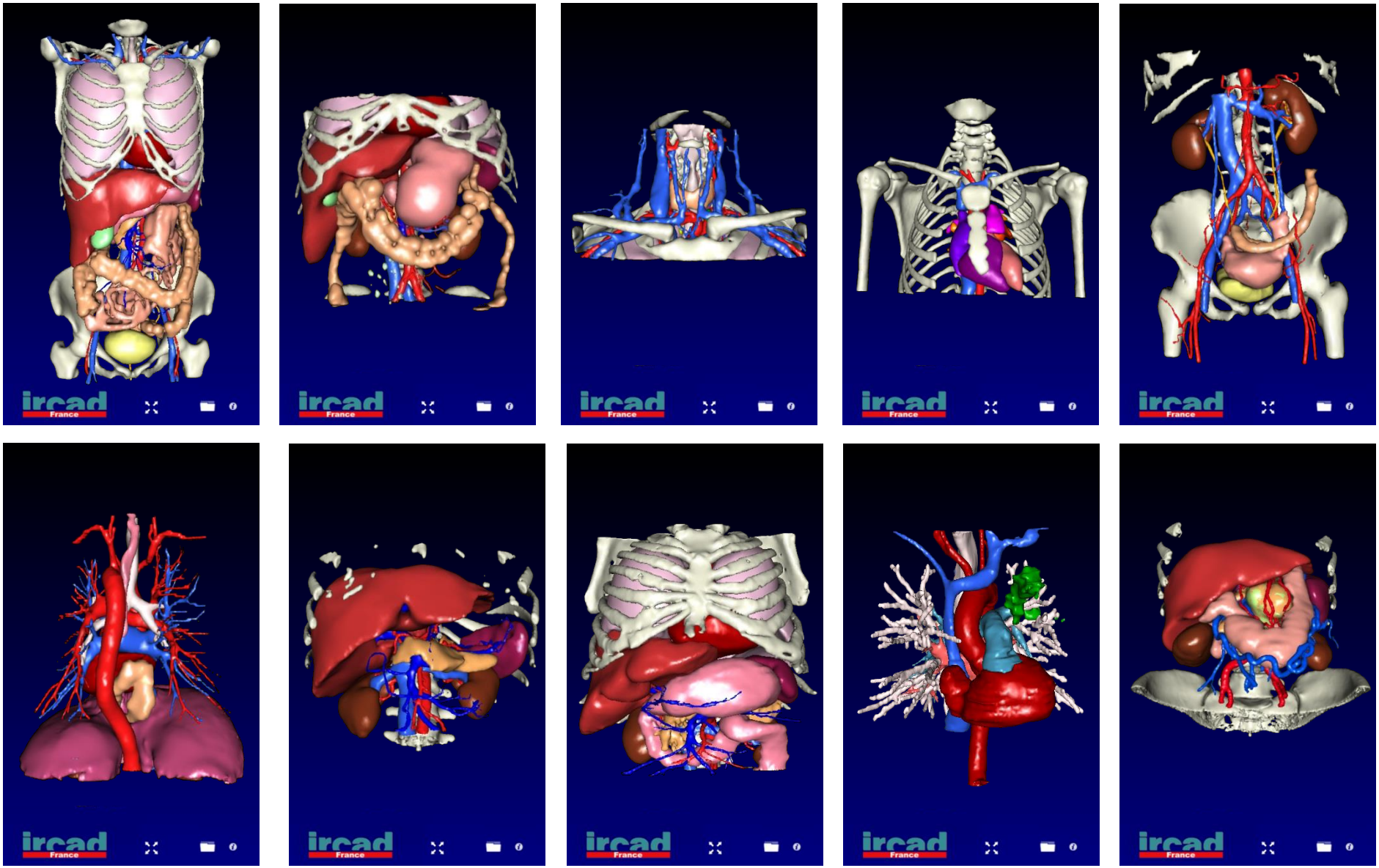
Intraoperative Use of Visible Patient



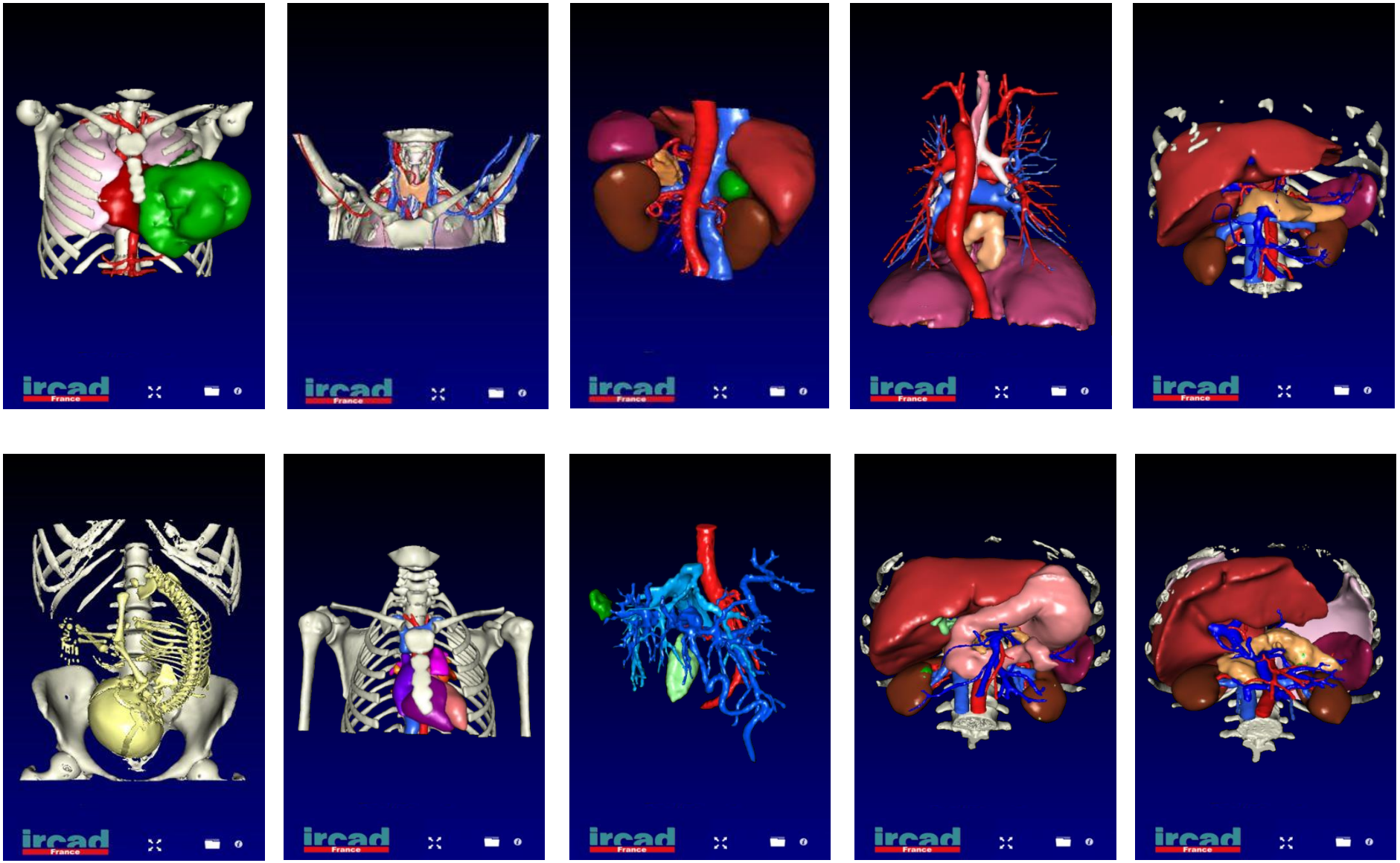
IHU – IRCAD : R&D Objectives

Education & Network

Free IRCAD Visualization software



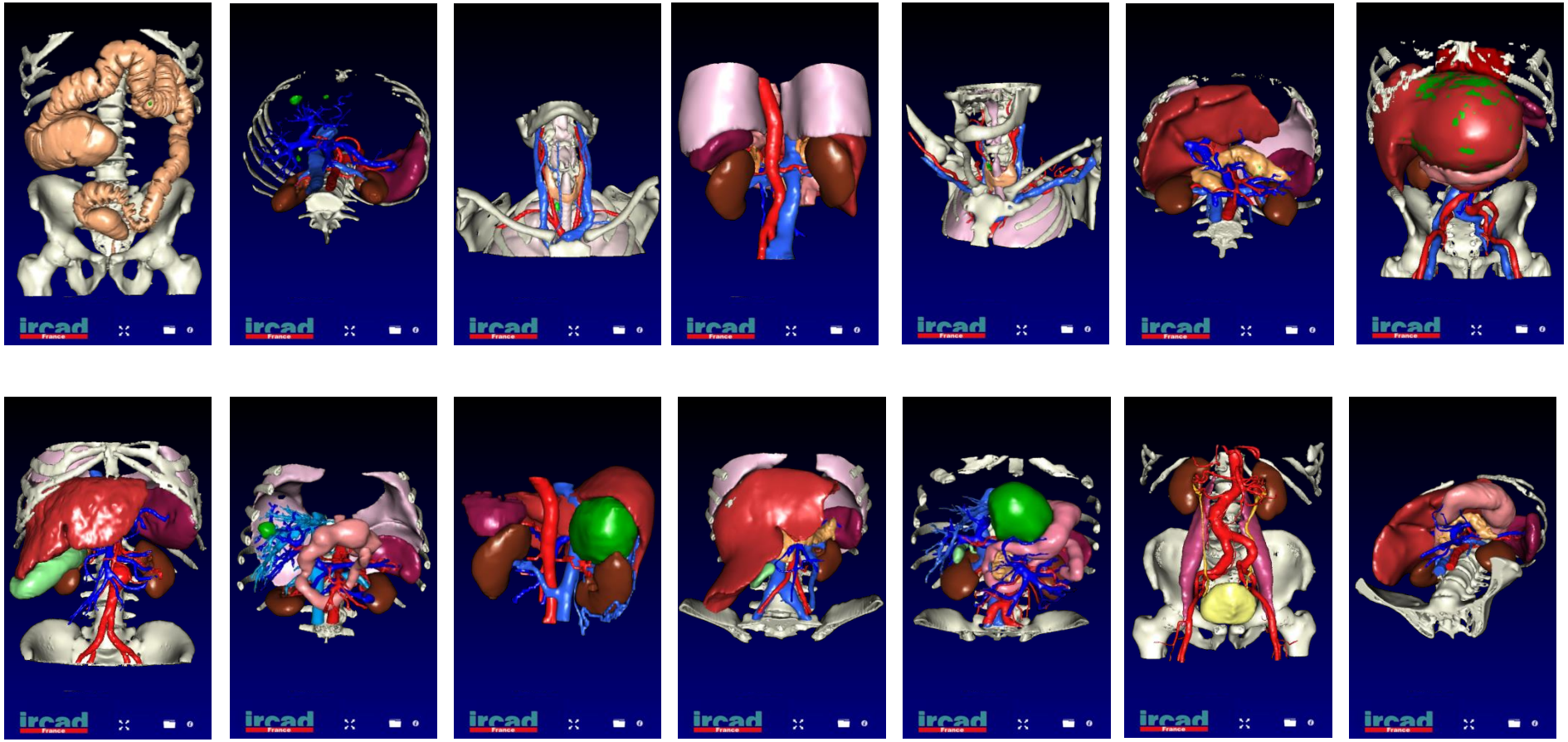
Free IRCAD Visualization software



Free IRCAD Visualization software

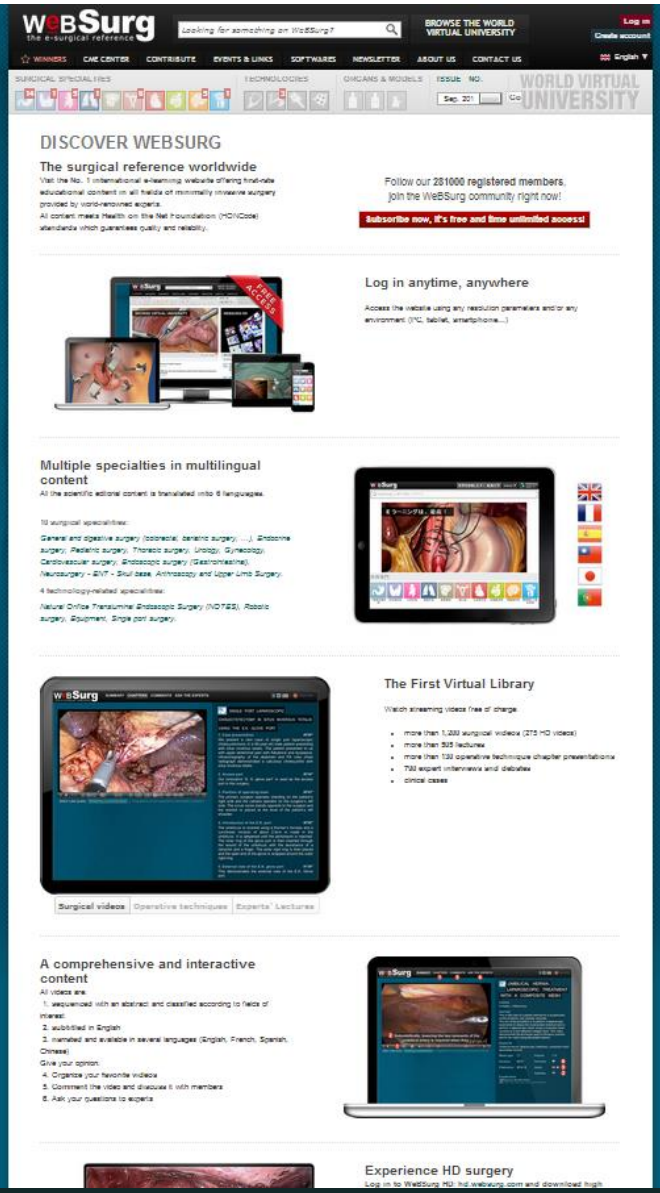
+14 clinical cases with operative video on websurg

http://www.websurg.com/softwares/vr-render/videos.php



www.websurg.com : FREE !!!

>280,000 members



IHU – IRCAD : R&D Objectives

Tracking & Augmented reality

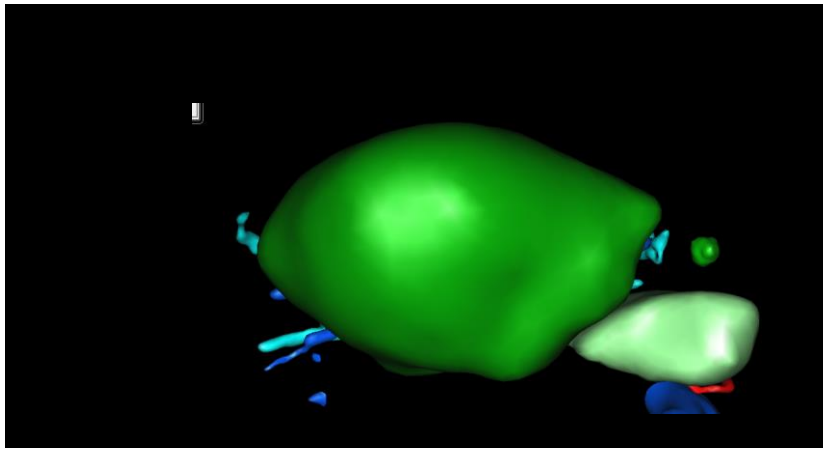
Augmented Reality Assisted Surgery

Current Available Systems for liver

- CAScination : Optical tracking & Rigid registration
- PathFinder : Optical tracking & Rigid registration

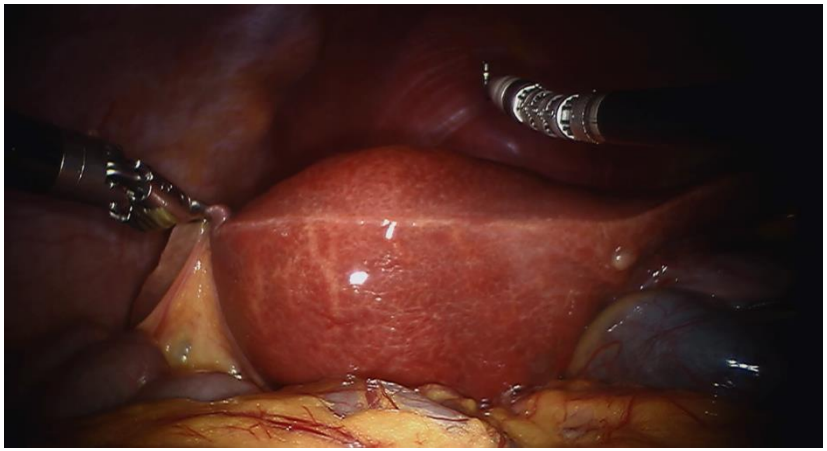
These systems are not Augmented Reality
But Augmented Virtuality !!!

What do we call “Augmented Reality”?



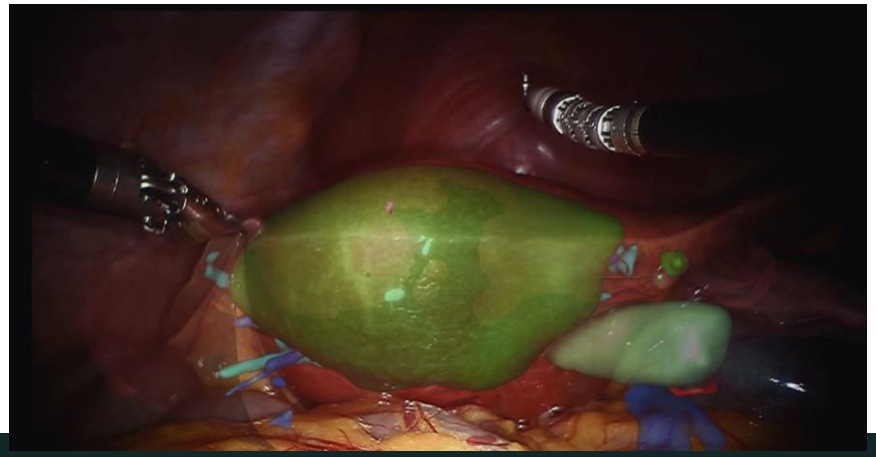
3D virtual Image

+



Video Image

= Augmented Reality



Augmented Reality Components

1: Virtual 3D images

2. AR Visualisation System

3. Registration

4. Tracking

Augmented Reality Components

1: Definition of virtual data

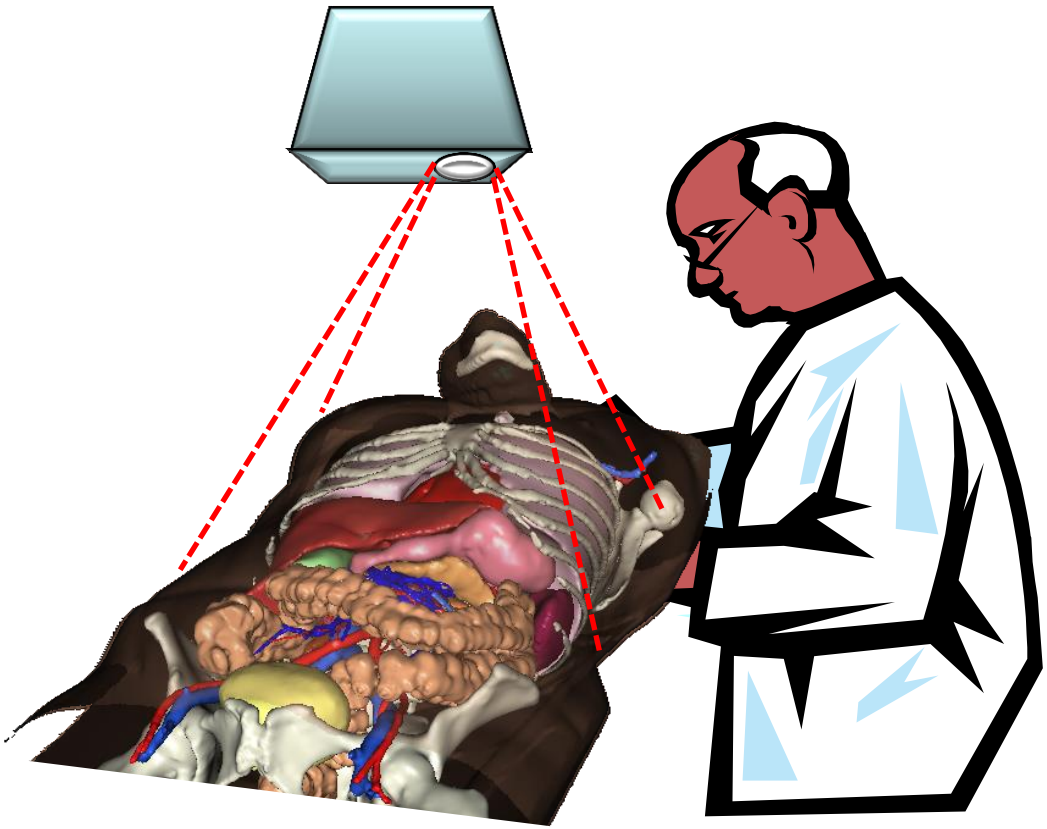
2. AR Visualisation Systems

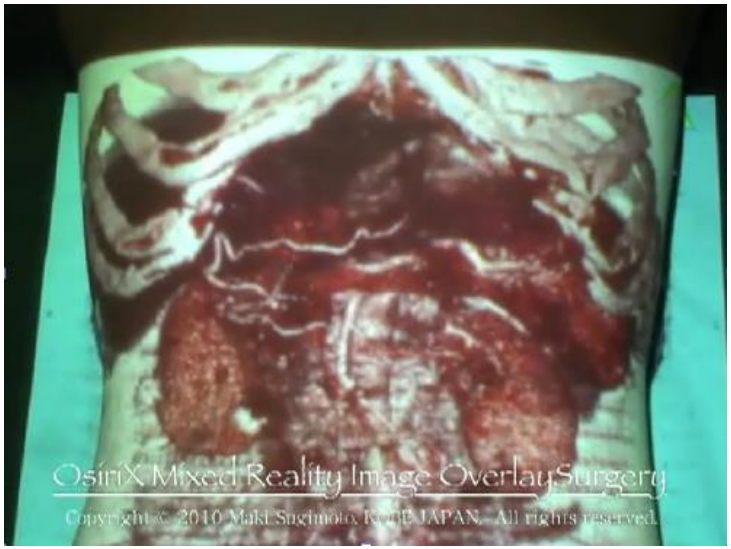
3. Registration

4. Tracking

Augmented Reality Visualisation systems

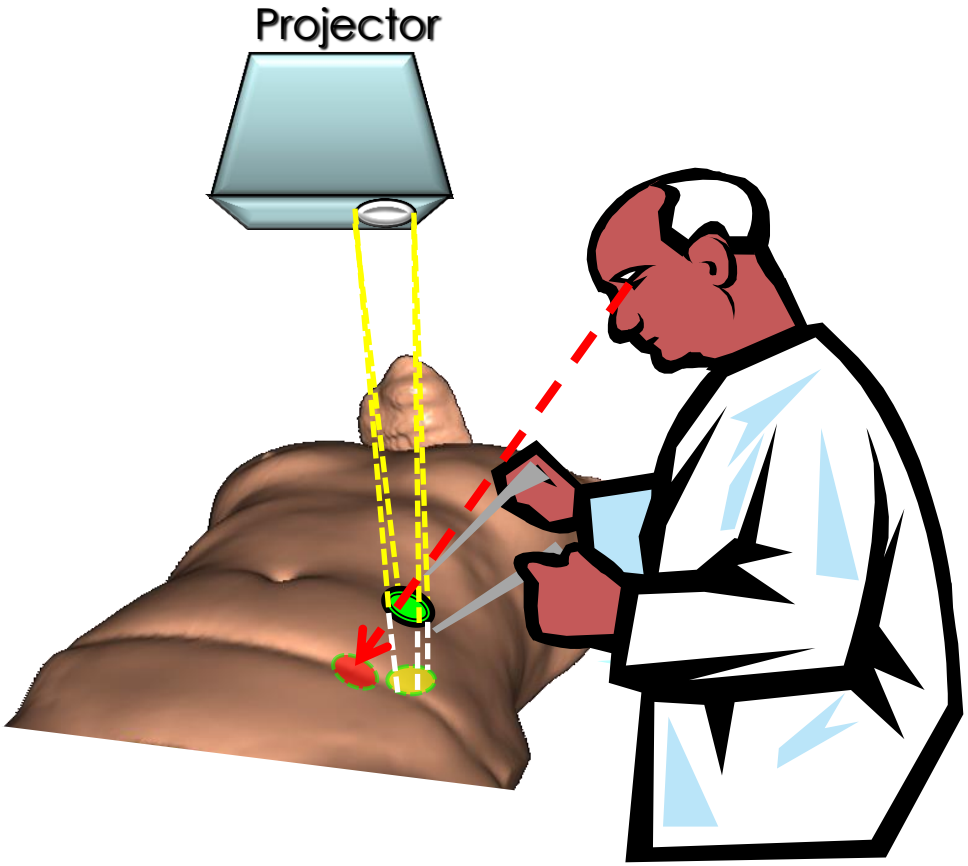
Projection





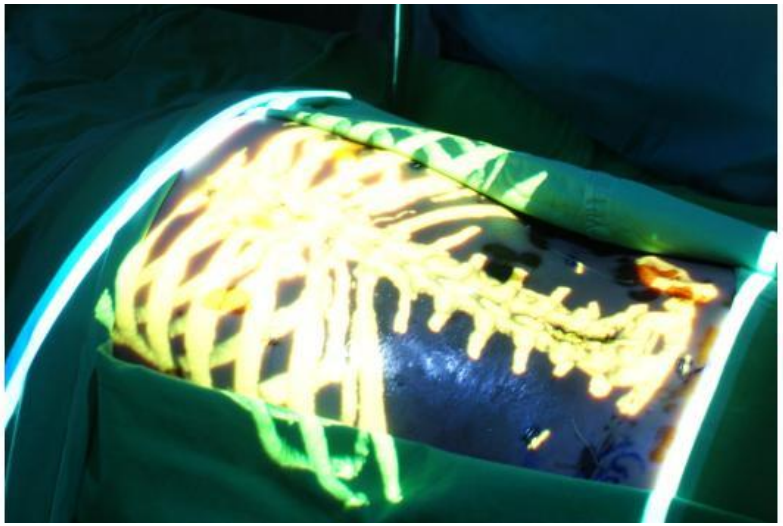
Dr. Maki Sugimoto with Osirix (opensource software running only on MacOs)

WARNING : MAJOR ERROR of the Projection



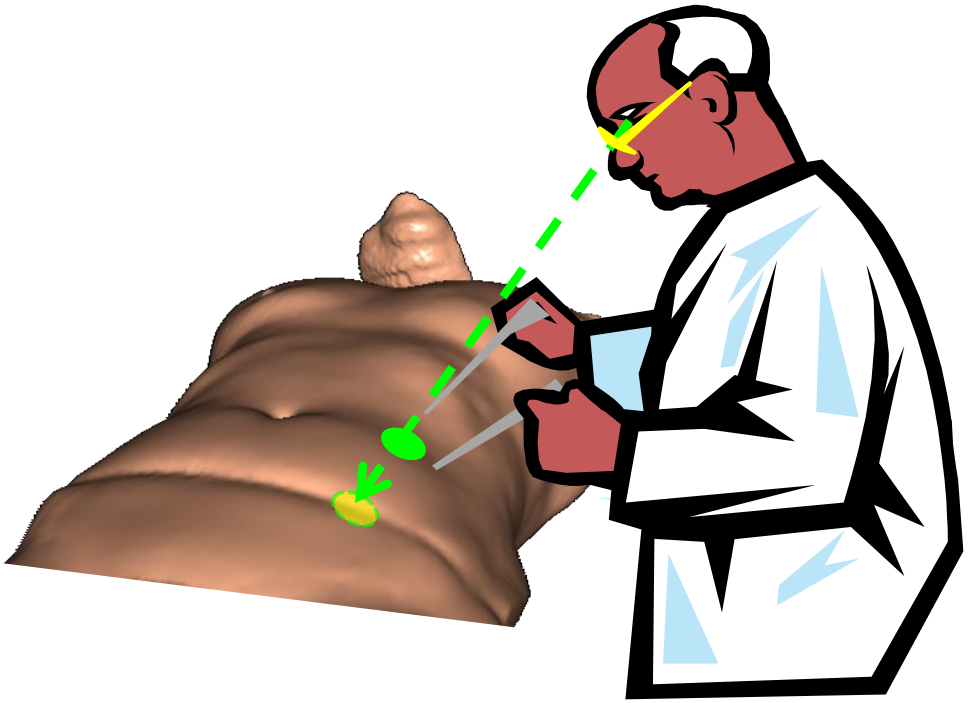
WARNING : MAJOR ERROR of the Projection

Should be used only for underskin structures



IRCAD Taiwan : Spinal surgery
Fast positionning of the C-Arm for Needle placement

WARNING : MAJOR ERROR of the Projection



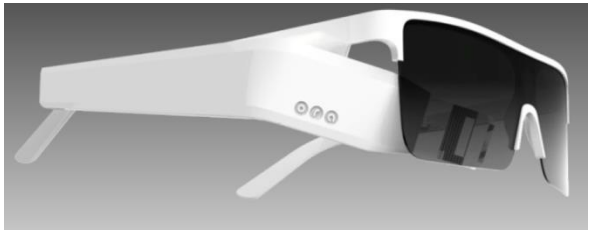
Augmented Reality Visualisation systems

See-Through Glasses: More & more solutions

Lumus

Epson

Optinvent



scalar

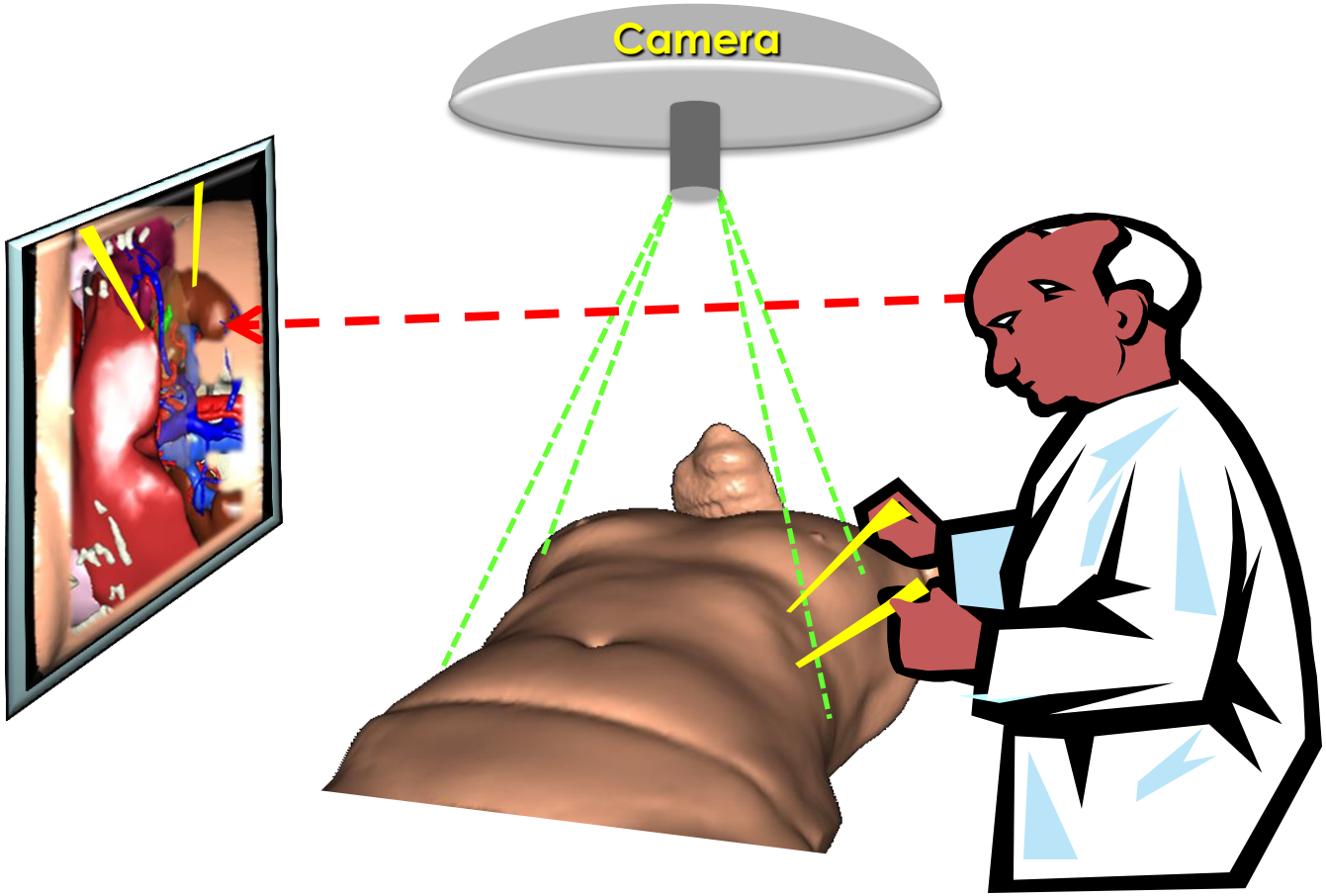
Google

Laster Technology

Brother

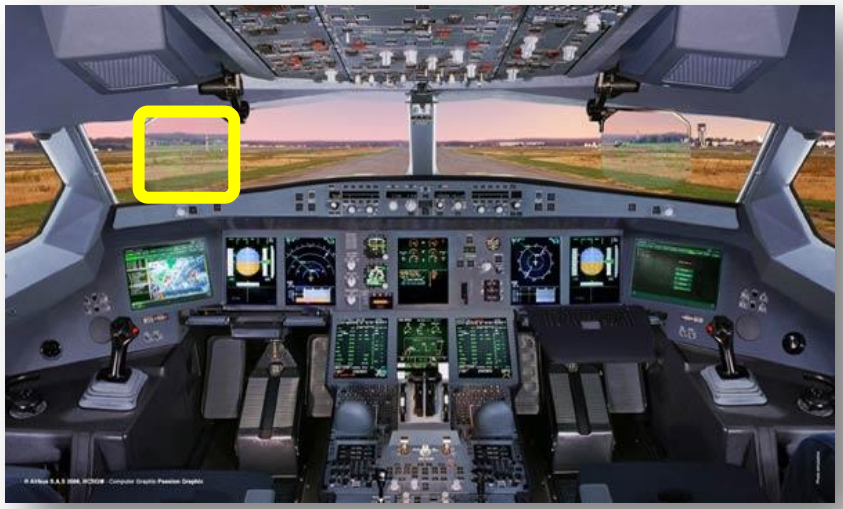
Vuzix

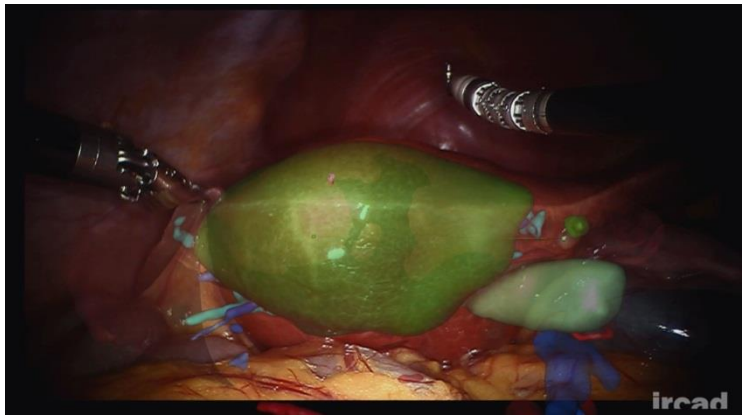
Augmented Reality Visualisation systems



Augmented Reality Visualisation systems

Best solution for MIS : Usual surgical screen





Augmented Reality Components

1: Definition of virtual data

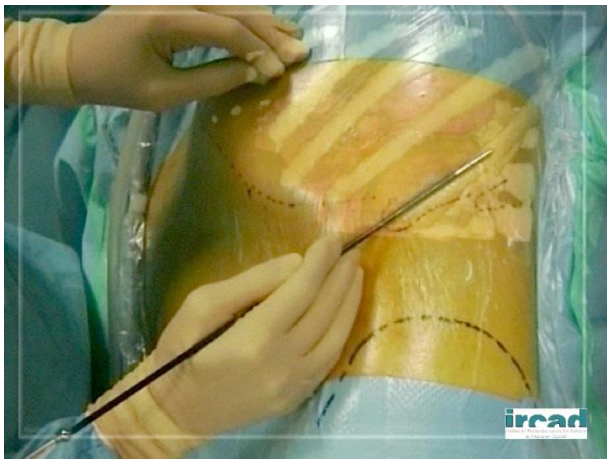
2. Augmented Reality Visualisation

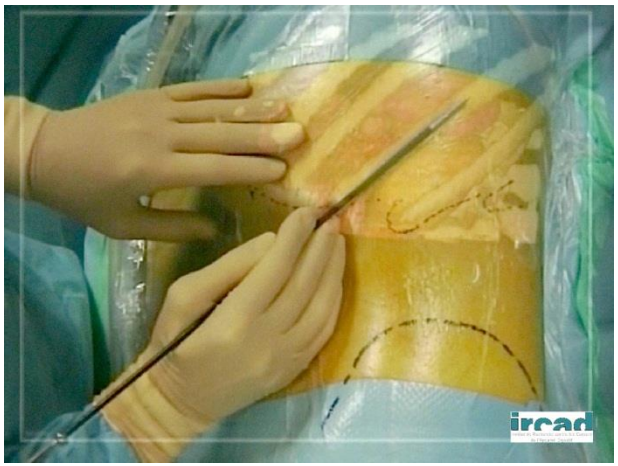
3. Registration

4. Tracking

IRCAD Interactive Augmented Reality

Interactive Registration

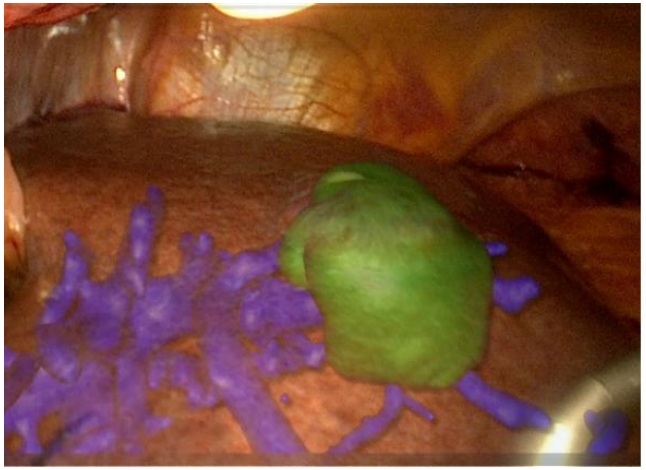




Use of underskin landmarks (published in Jama 2004)

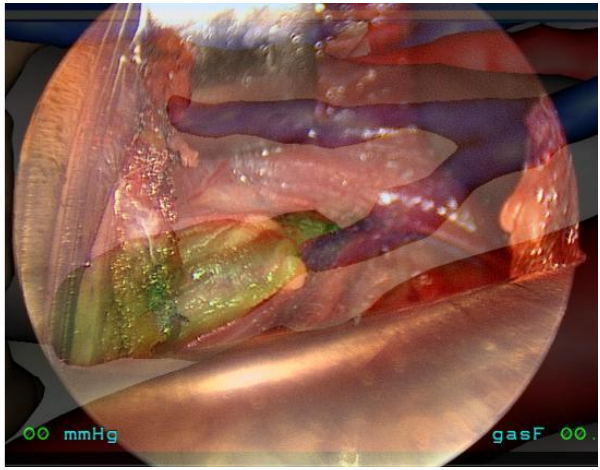
Interactive Registration

Hepatic surgery



Pancreatic Surgery

Parathyroid Surgery



Interactive Registration

Conclusion
More than 50 Surgical Procedure

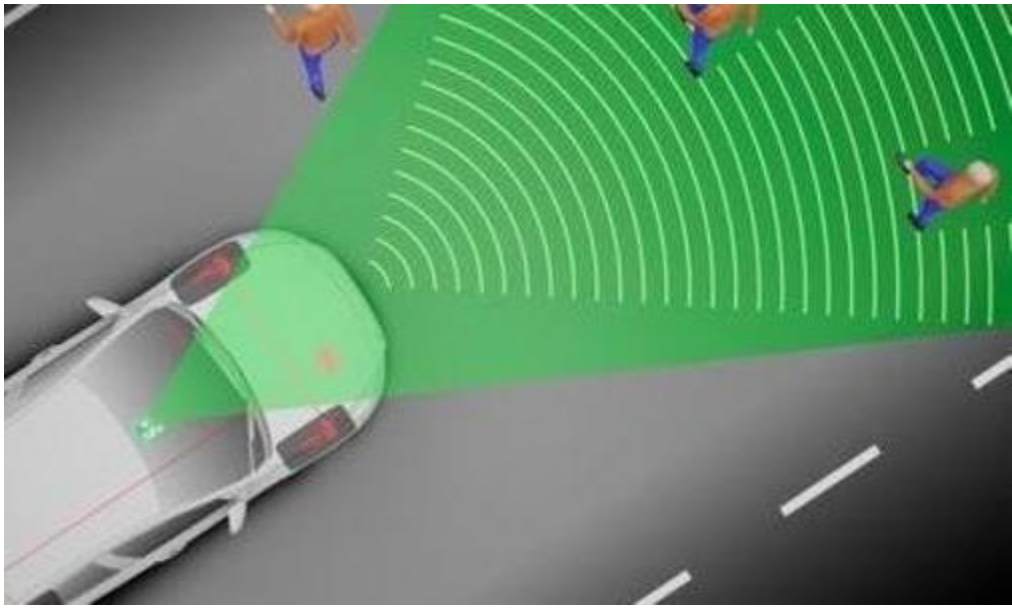
➔ Highly Efficient with Good accuracy

➔ BUT fully user dependent

➔ Require specific training in 3D manipulation

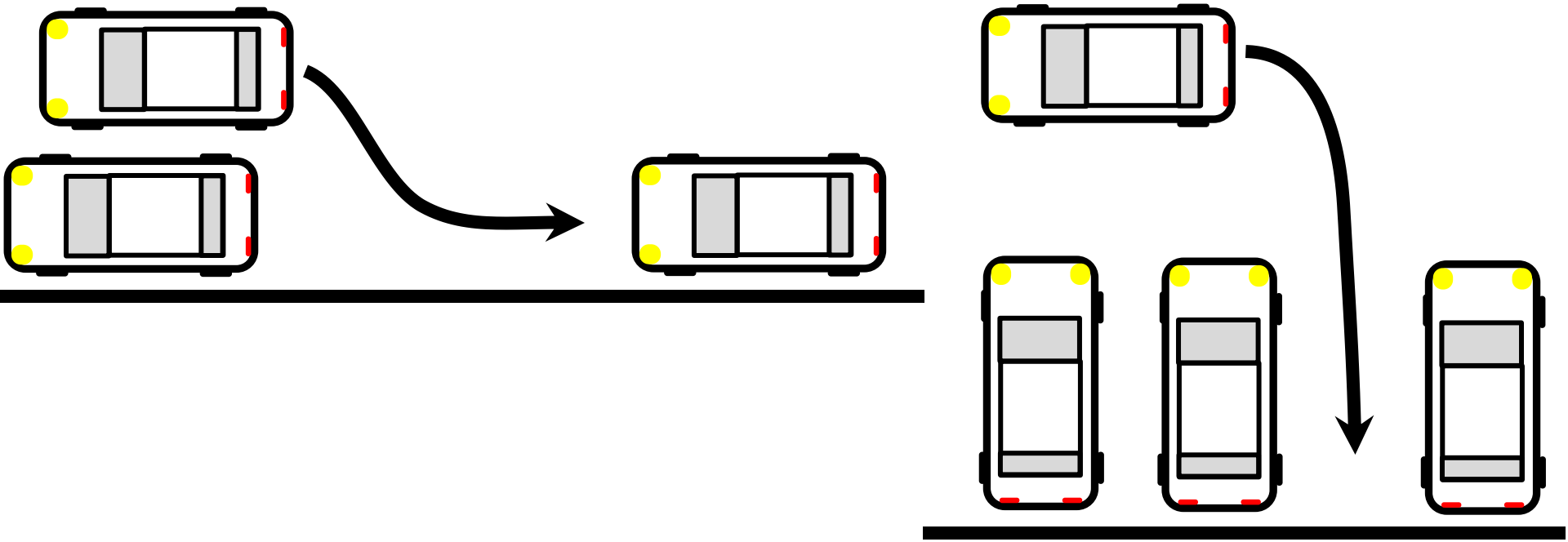
➔ Only rigid registration

Add automation through signal analysis



Environment & Movement Tracking

Exemple : Parking AR Assistance



AR Assistance will be linked to the configuration ➔ Not 1 solution

Application to Surgery

1: It is mandatory to understand the **Surgical Workflow** of the procedure

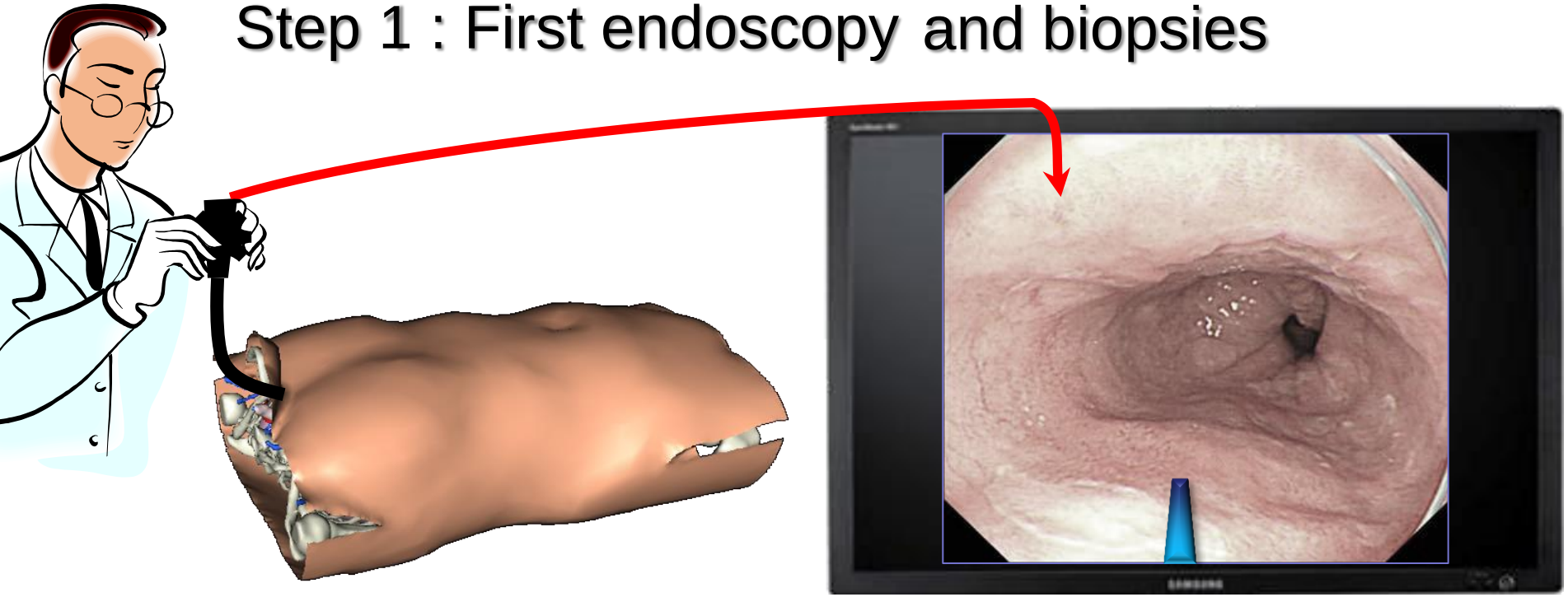
2: It is mandatory to develop **specific AR** assistance from this workflow

➔ Several procedure = several solution
Each Step needs its own adapted solution

Exemple 1 : Gastroenterology

The Surgical Workflow of the procedure

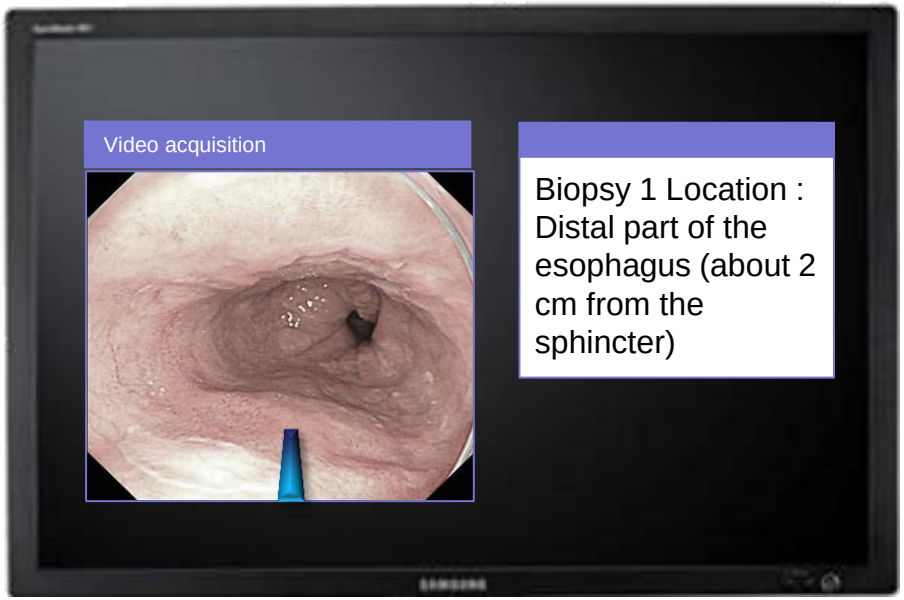
Step 1 : First endoscopy and biopsies



Exemple 1 : Gastroenterology

The Surgical Workflow of the procedure

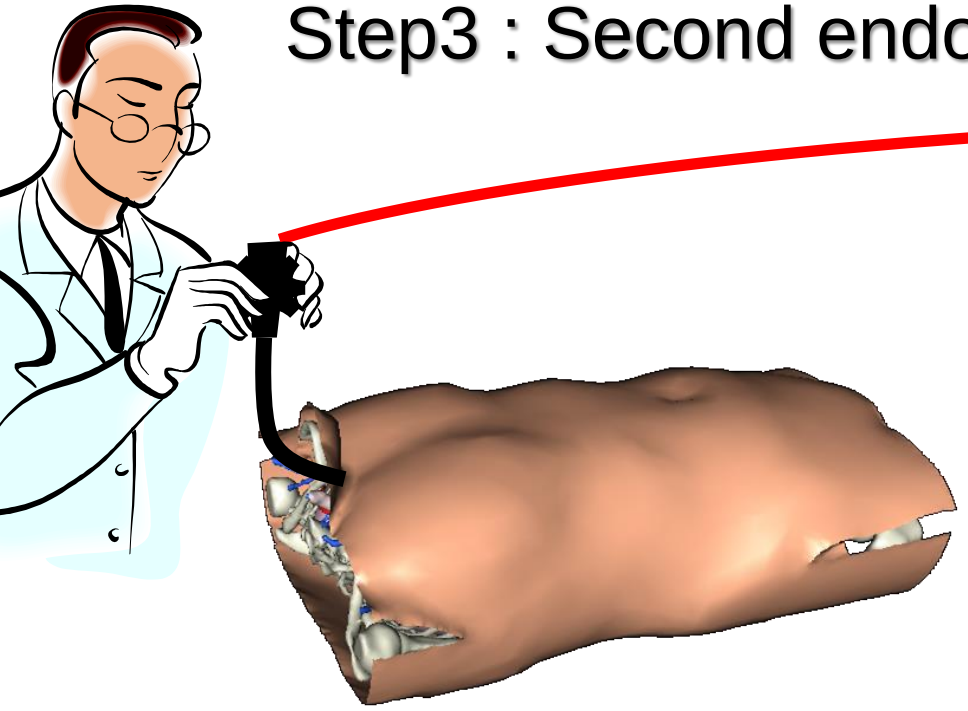
Step 2 : Post analysis and report

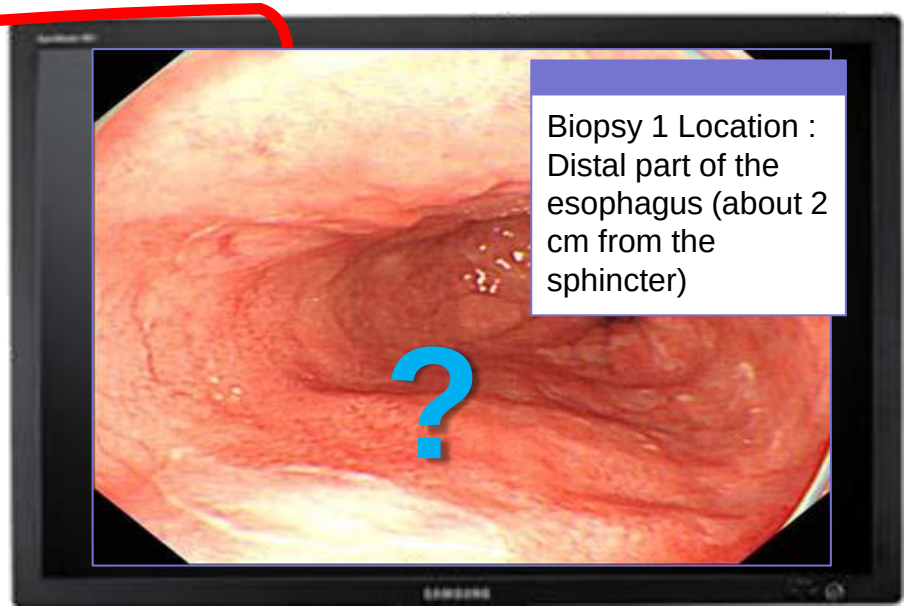


Exemple 1 : Gastroenterology

The Surgical Workflow of the procedure

Step3 : Second endoscopy and biopsies





Where was the biopsy ?

Solution 1 : Gastroenterology

Feature tracking : Pete Mountney (ICL/Siemens)

MaunaKea Technology Confocal virtual biopsy

Solution 1 : Gastroenterology

Feature tracking **Benefit** :

No need of new device but a computer

MAIN LIMITS :

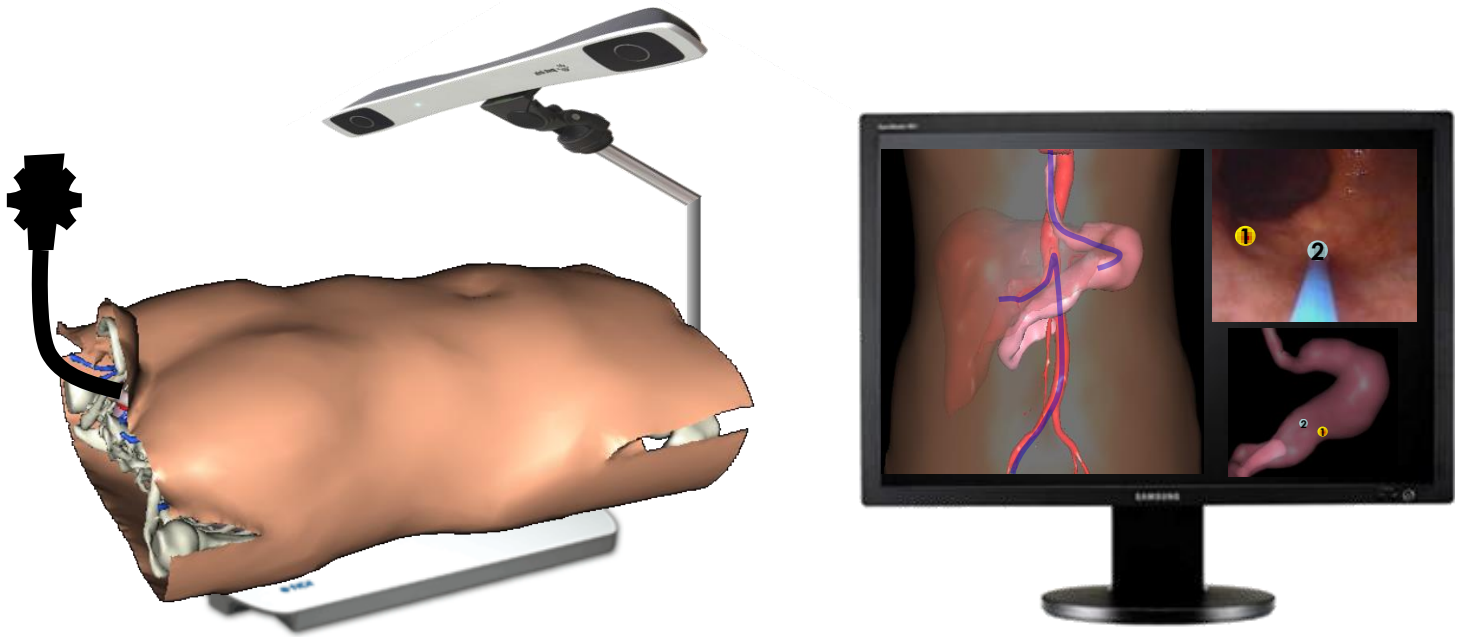
1: Should not work if lesion evolution

2: Complex to assume for CE-Mark of FDA

➔ Long time to market

Solution 2 : Gastroenterology

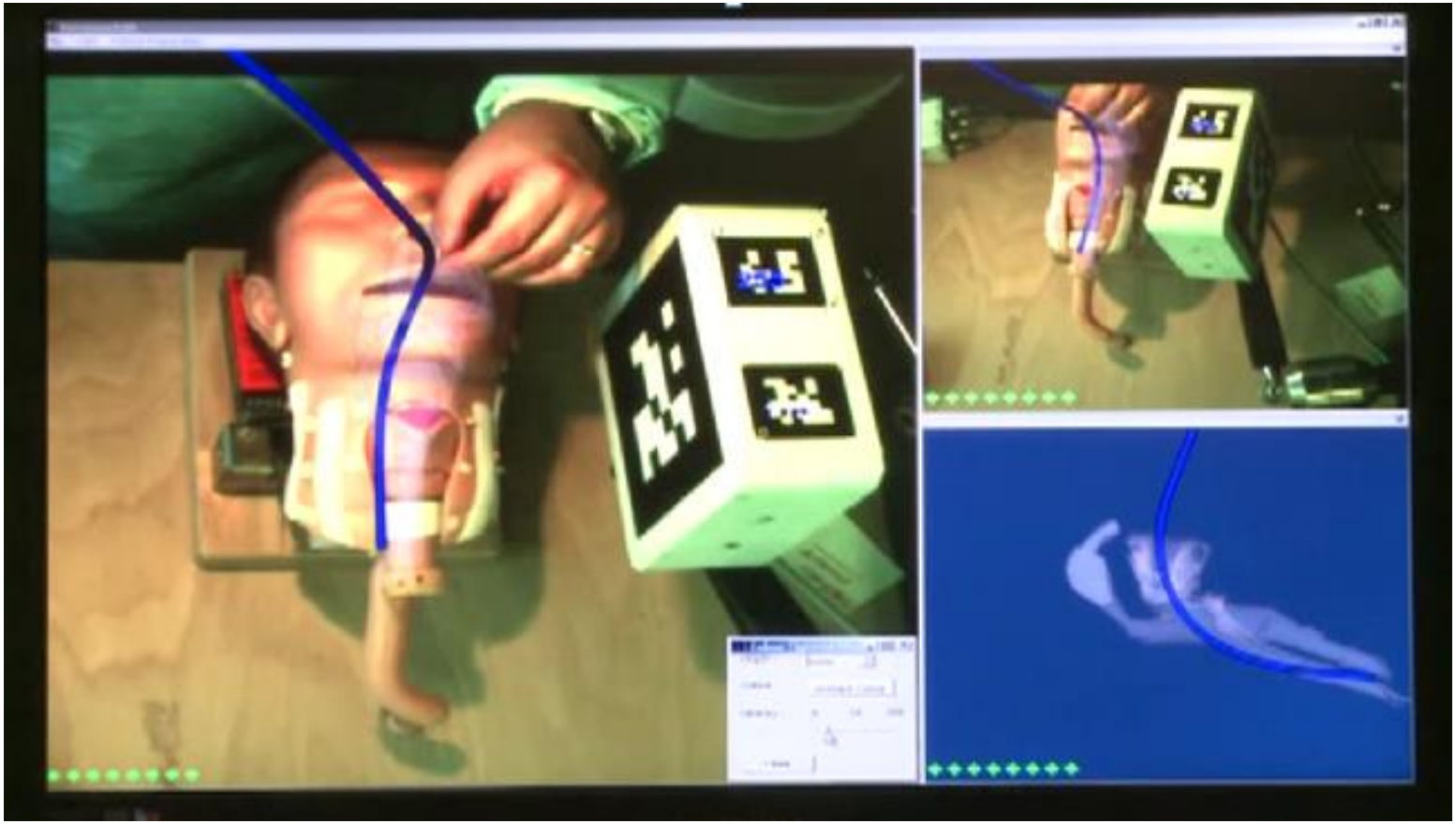
3D Localization of the endoscope or of a catheter in the patient with Augmented Reality information for surgeon Guidance



Aurora 5/6DOF Shape Tool ©NDI – IRCAD Design

Solution 2 : Gastroenterology

➔Electro-magnetic tracking

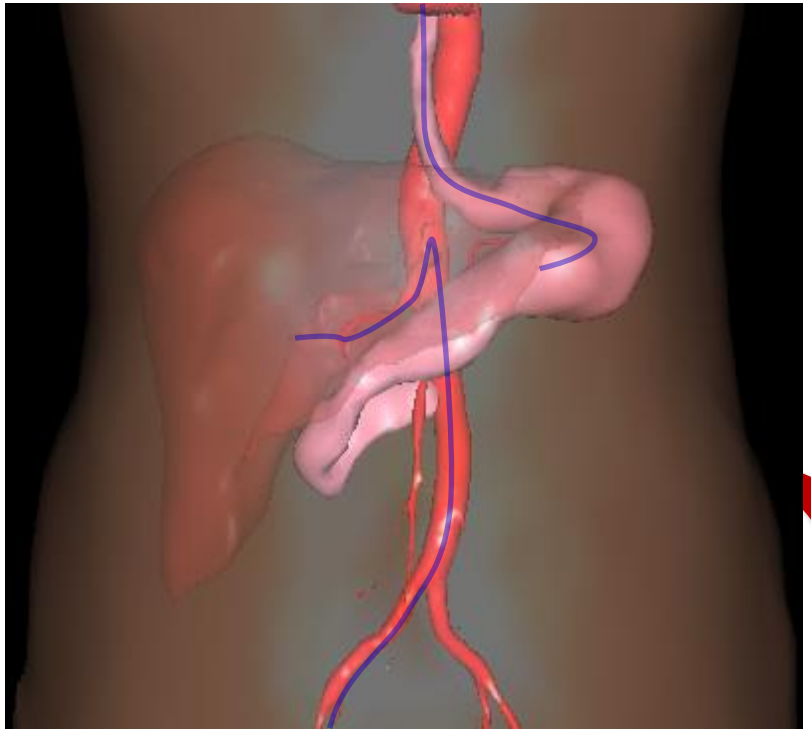


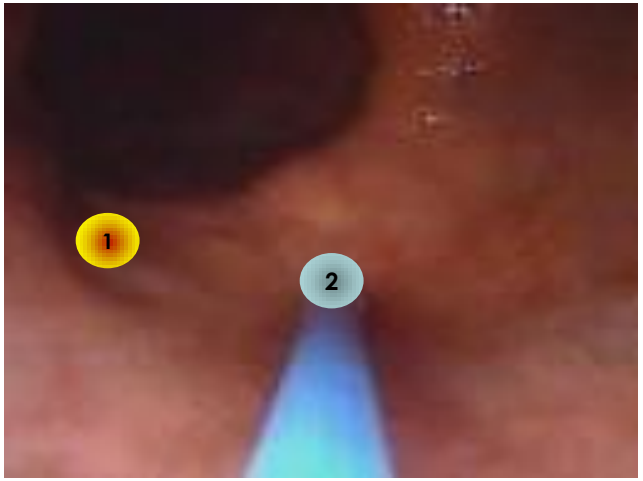
METRIS : US Patent 12/797209 – Karl Storz + IRCAD

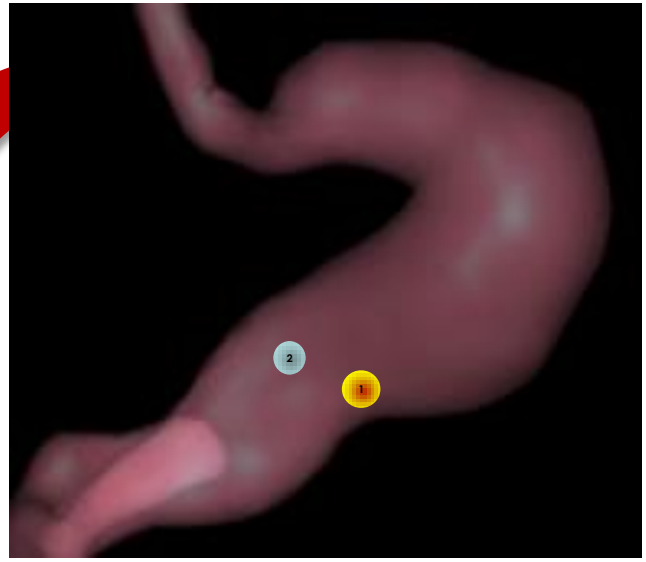
Solution 2 : Gastroenterology

Augmented Reality for NOTES : METRIS
Nicolau et al., Surgical Oncology 2011

Solution 2 : Gastroenterology





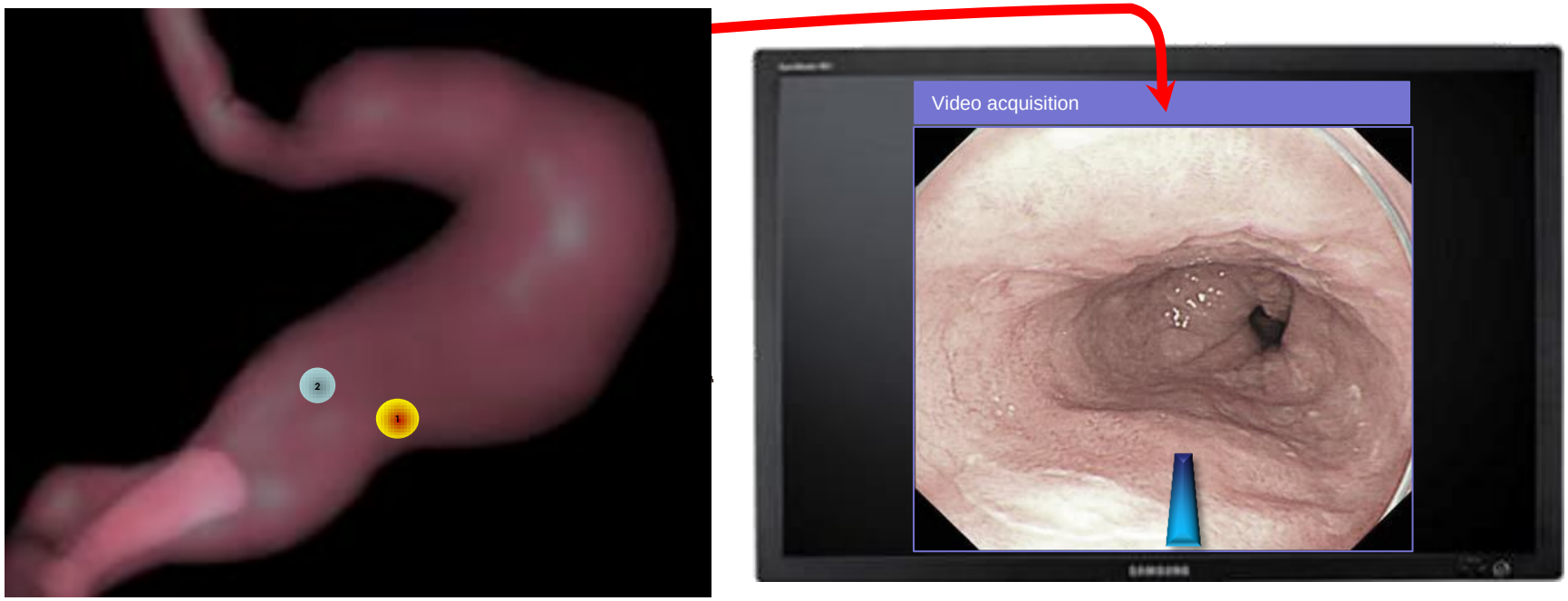


Main Limits :

Need Medical image & Patient Modelling

Solution 2 : Gastroenterology

Routine Reality: No preoperative image
Pathologies not visible in such images

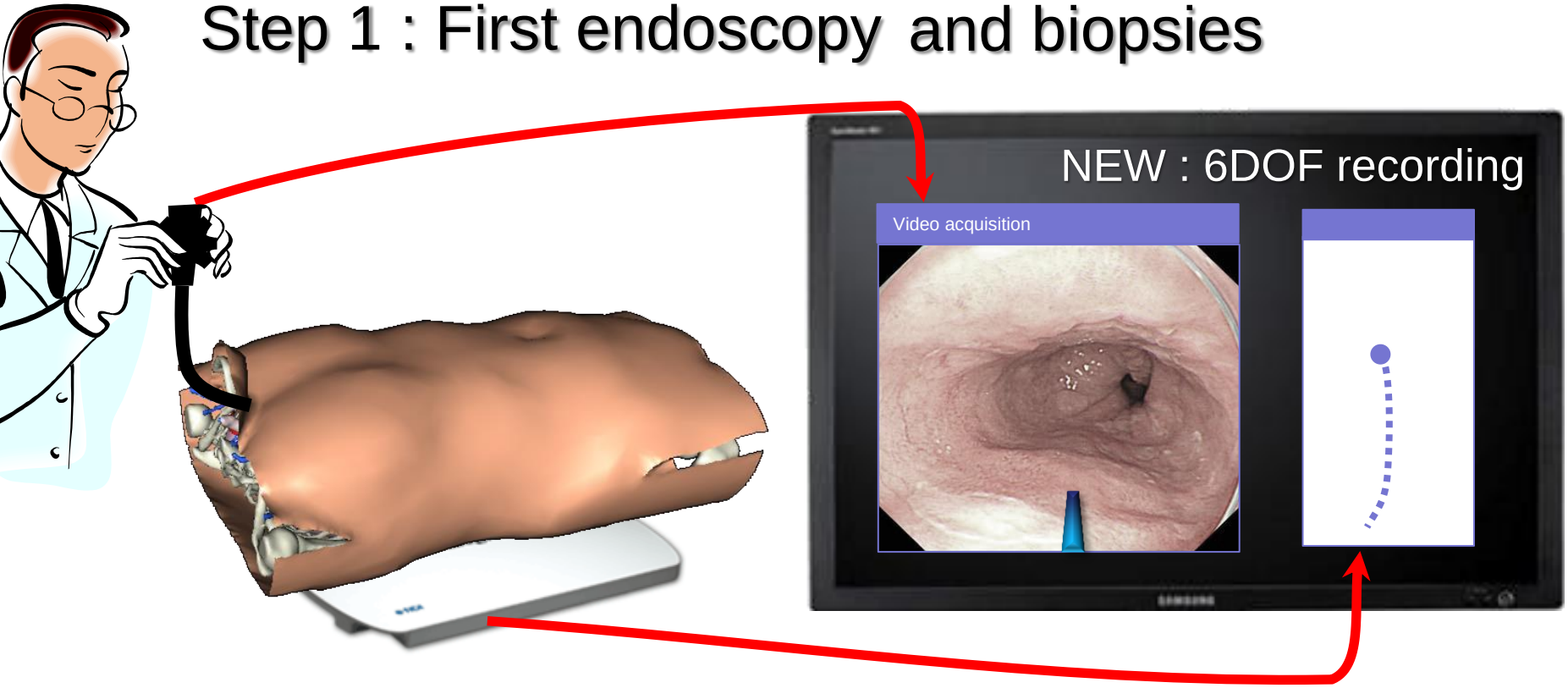


Not compatible with the Clinical Workflow

Solution 3: Gastroenterology

6 DOF Electro-magnetic tracking

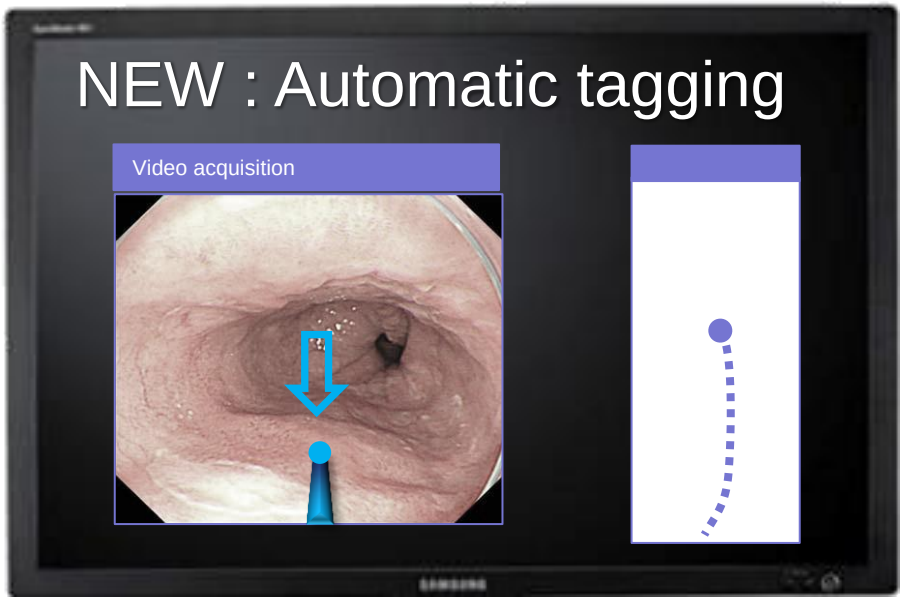
Step 1 : First endoscopy and biopsies



Solution 3: Gastroenterology

6 DOF Electro-magnetic tracking

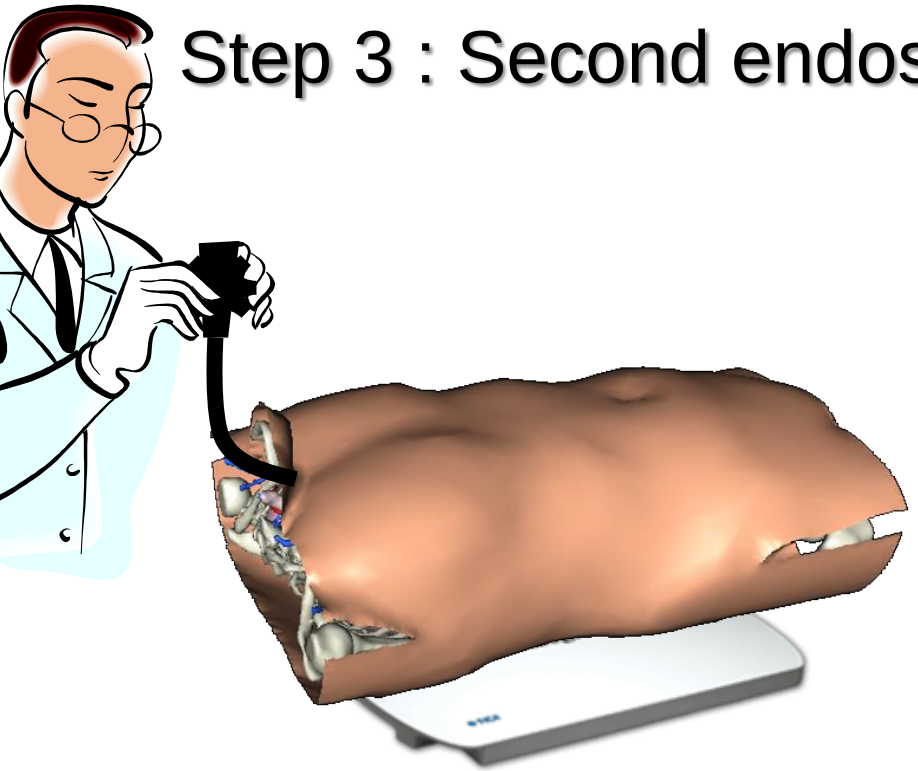
Step 2 : Post analysis and tagging



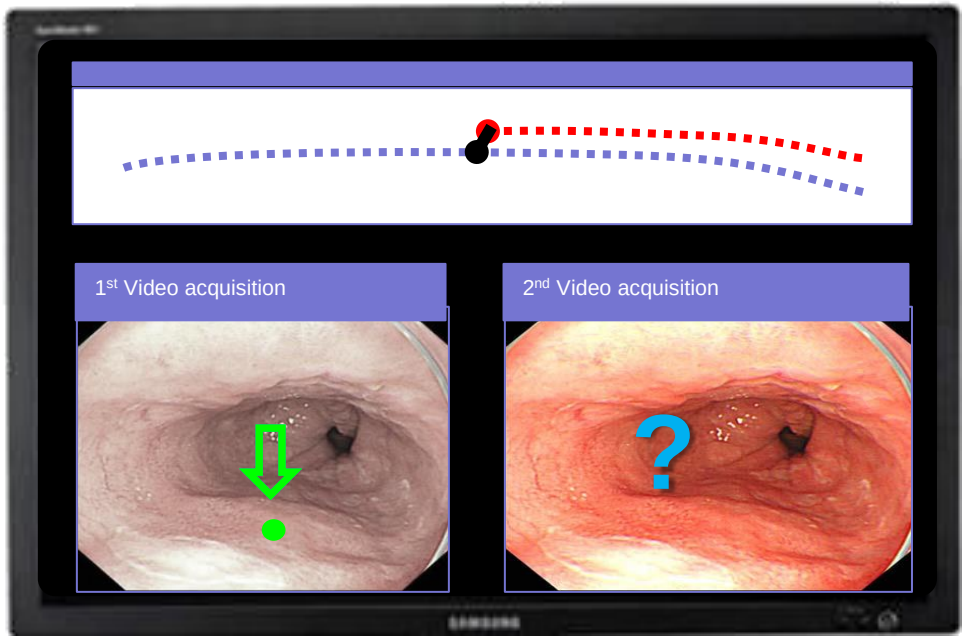
+ 6DOF location

Solution 3: Gastroenterology

6 DOF Electro-magnetic tracking

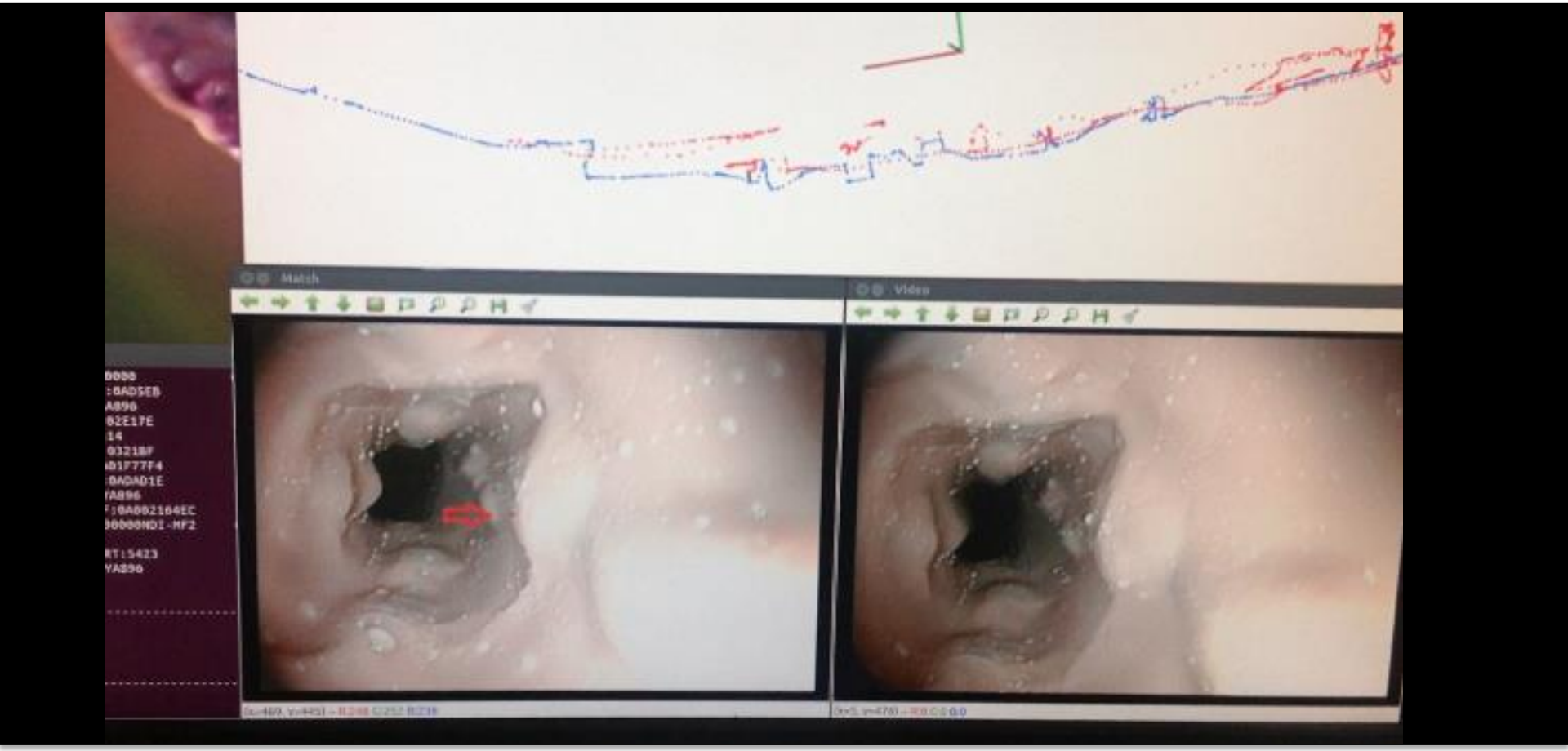


Step 3 : Second endoscopy **+ new synchronisation**



Solution 3: Gastroenterology

6 DOF Electro-magnetic tracking



First Endoscopy

Live Endoscopy

Exemple 2 : MIS Liver Surgery

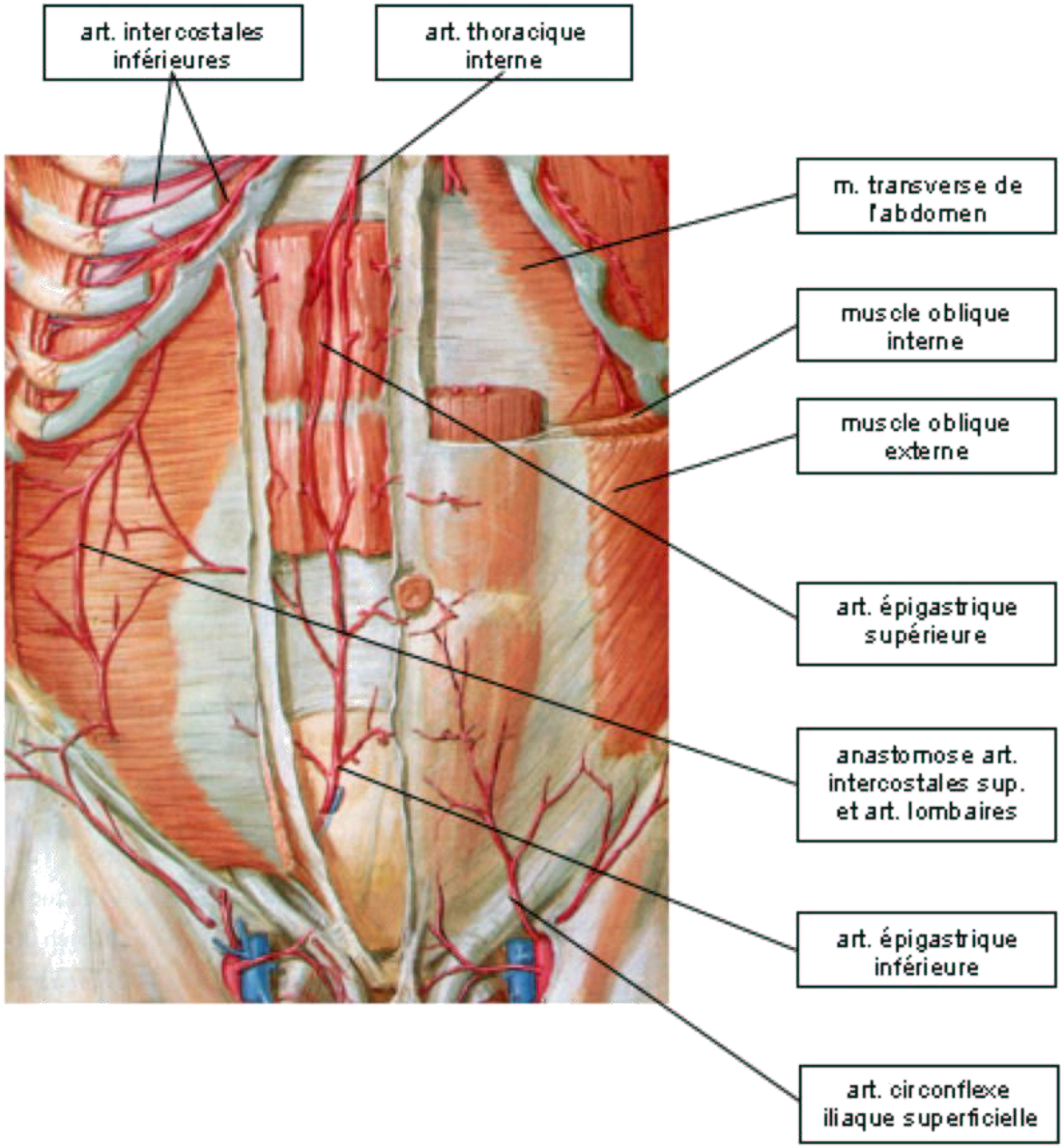
A Complex Workflow :

1. Veress Needle positionning
2. Pneumoperitoneum
3. Surgical Table Displacement
4. Trocart positionning
5. Laparoscopic Exploration
6. Removal of Liver attachment
7. Hile vessels control
8. Resection of the pathological liver
9. Endobag introduction and use
10. Resection of the skin for liver extraction
11. Liver extraction and skin suture

Step 1: Veres needle positionning

Risk 1 : Epigastric arteries injury

Consequence: Lost 5 to 15mn

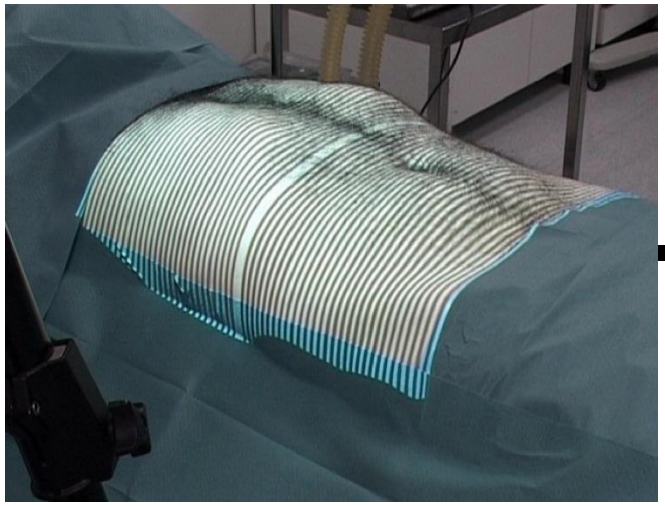


Step 1: Veres needle positionning

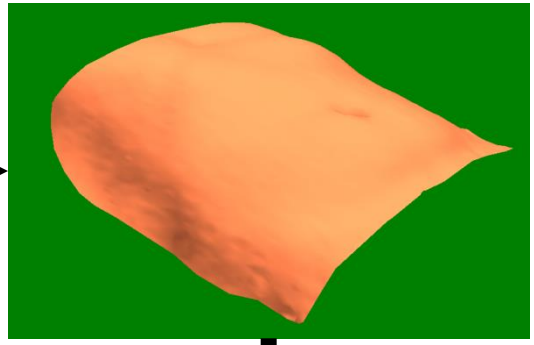
Risk 2 :
Liver, organs or abdominal vessels injury
+ Gaz insufluation in an organ

Consequence : conversion from MIS to open, can lead to the death of the patient

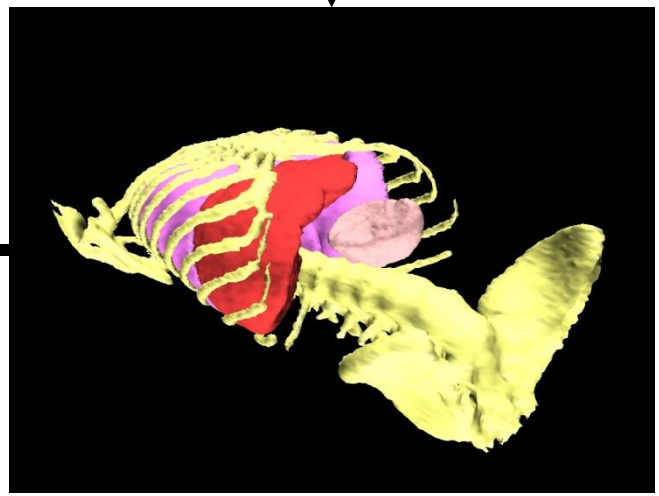
Step 1 : AR- Solution

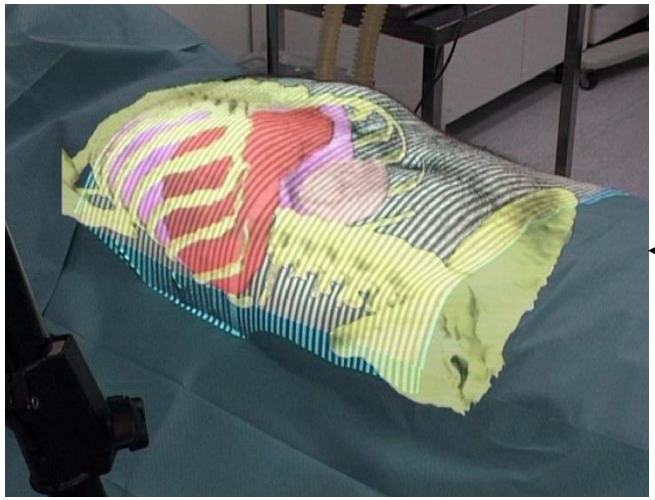


Automatic surface extraction

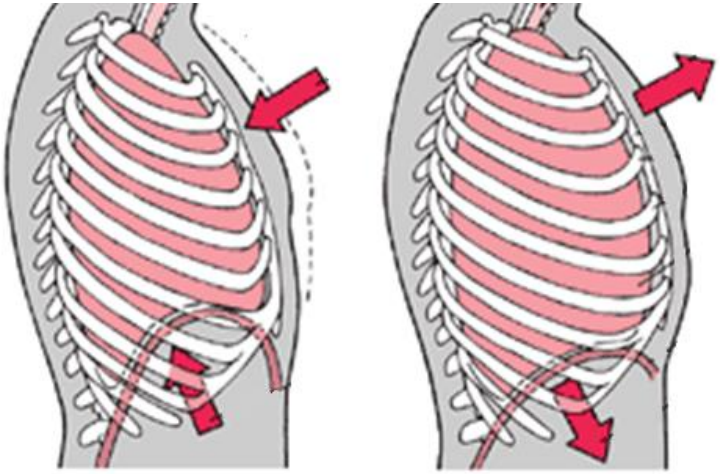


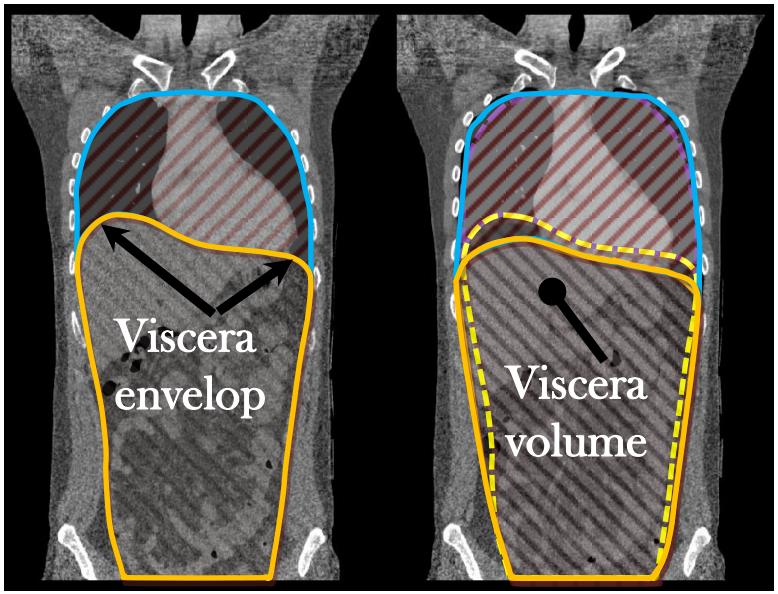
Automatic
Registration

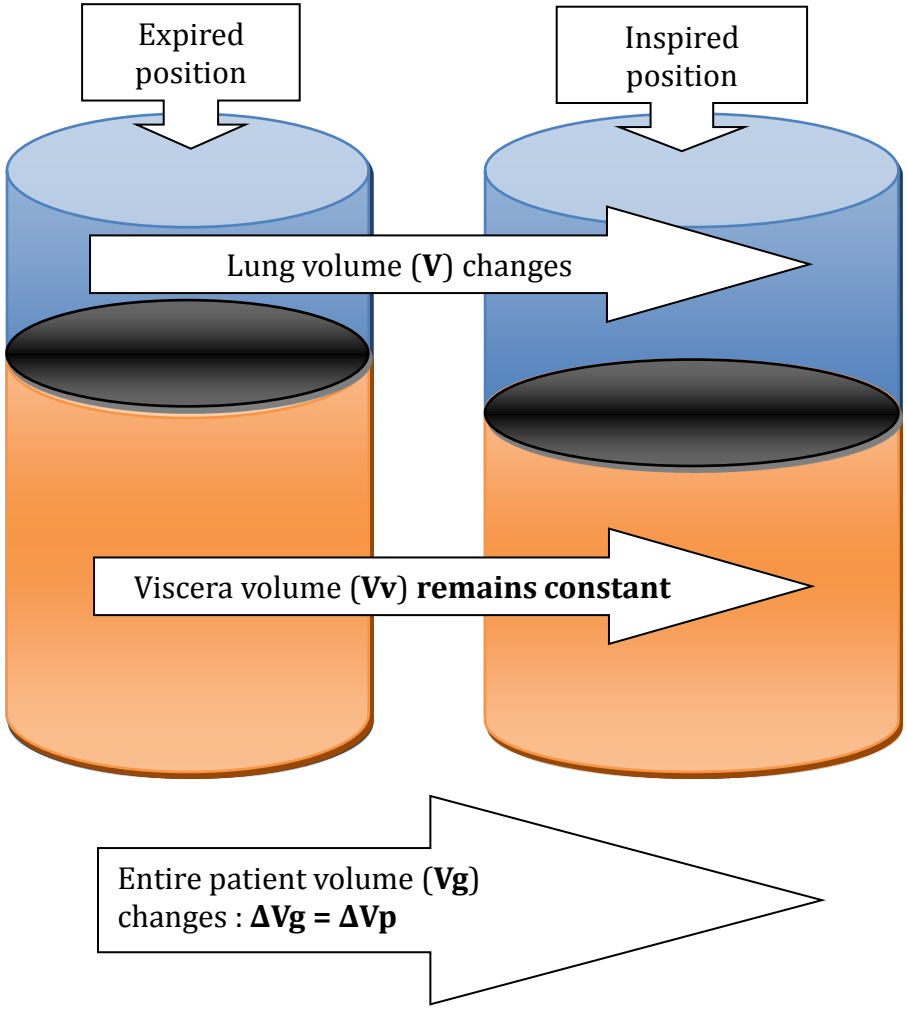




Breathing Analysis

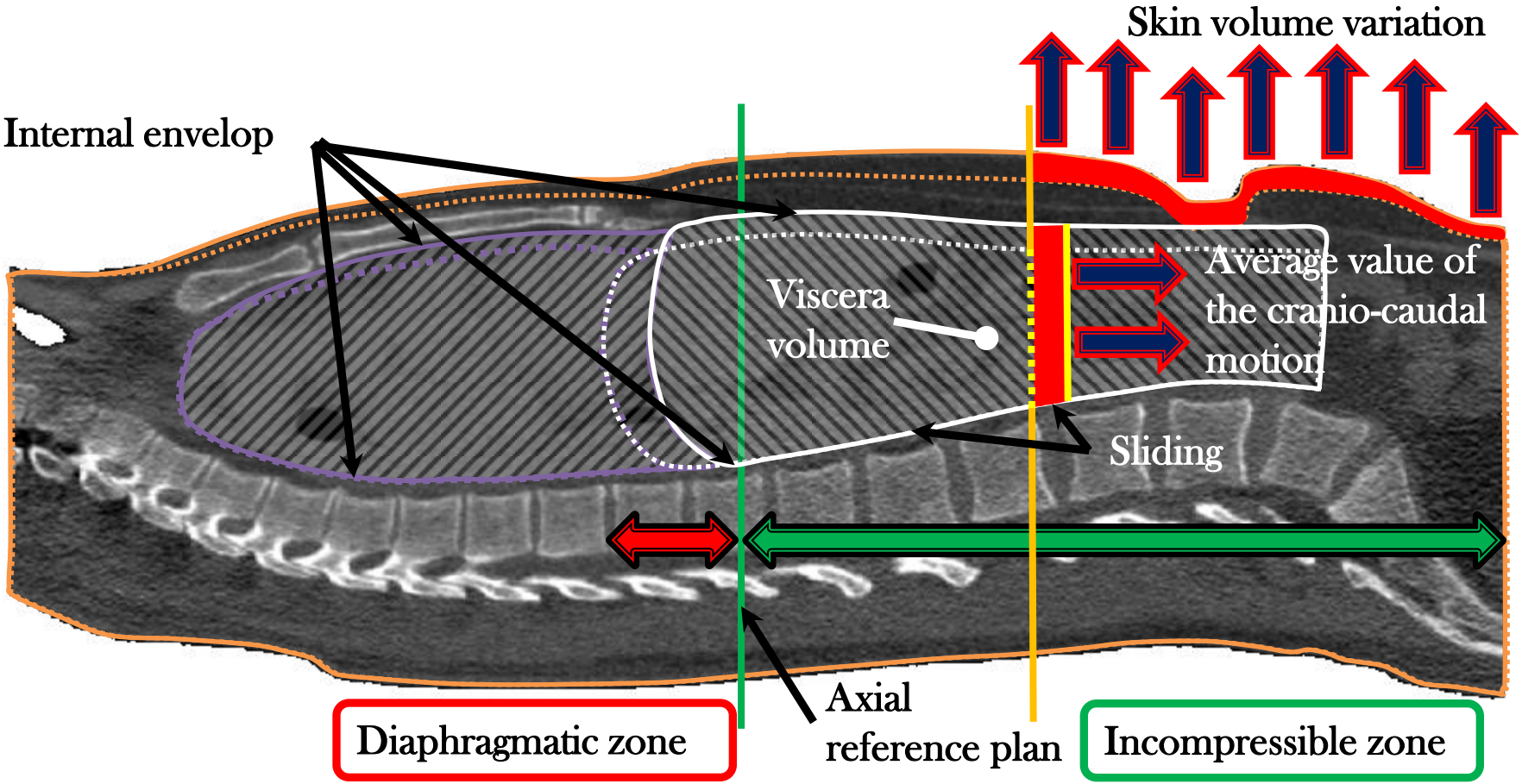






IRCAD's Method

Computation of the cranio-caudal average value



Automatic Registration: non rigid

A real-time predictive simulation of abdominal viscera position during quiet free breathing,

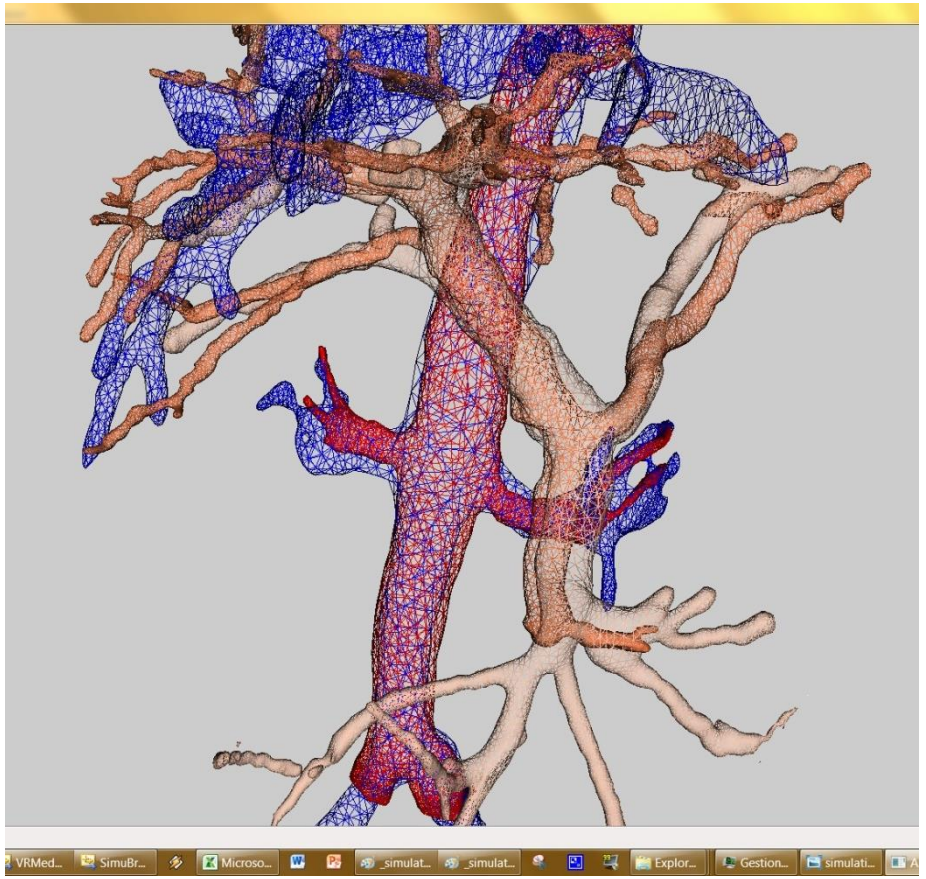
A. Hostettler et al., *Prog Biophys Mol Biol. 2010 Dec;103(2-3):169-84.*

Validation

Comparison between 2 position of breathing segmented CT and simulated position

Organs	Patient I	Patient II
Liver	2.4 mm	2.2 mm
Right Kidney	1.9 mm	1.7 mm
Left Kidney	1.7 mm	1.4 mm
Spleen	2.8 mm	2.3 mm
Pancreas	X	2.5 mm

Automatic Registration: non rigid

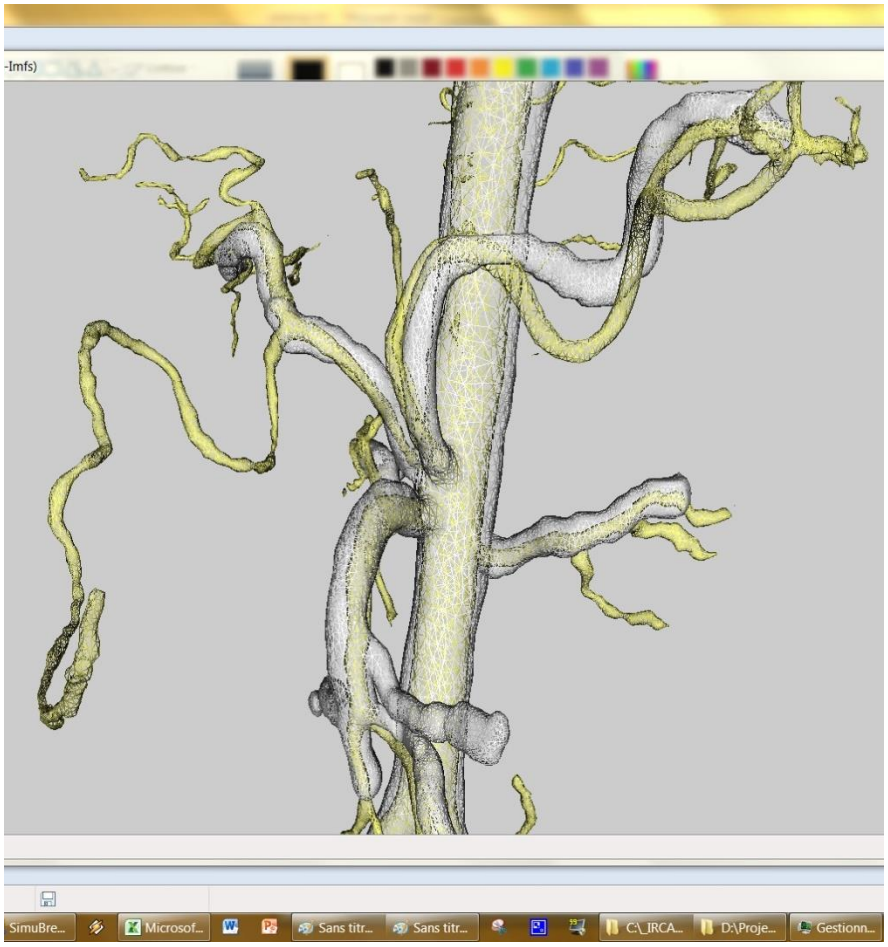


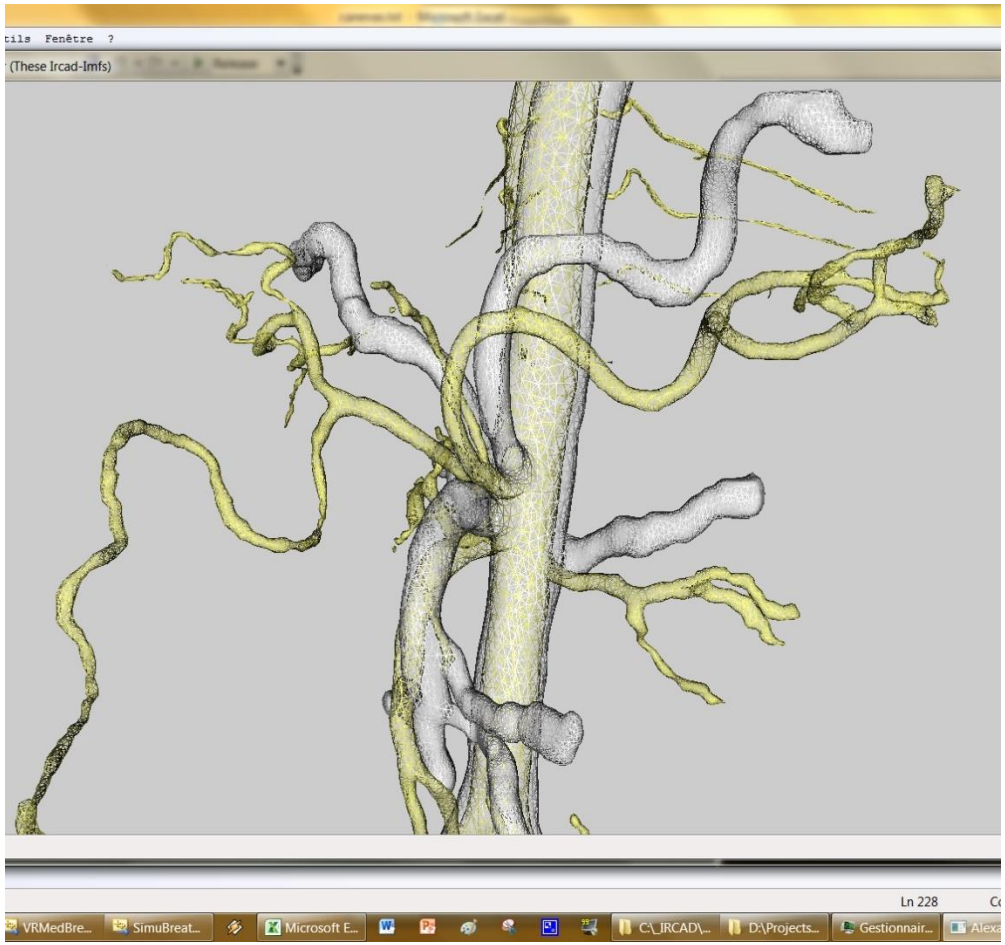
Before

After

Error on main veins < 1 mm (real-time)

Automatic Registration: non rigid



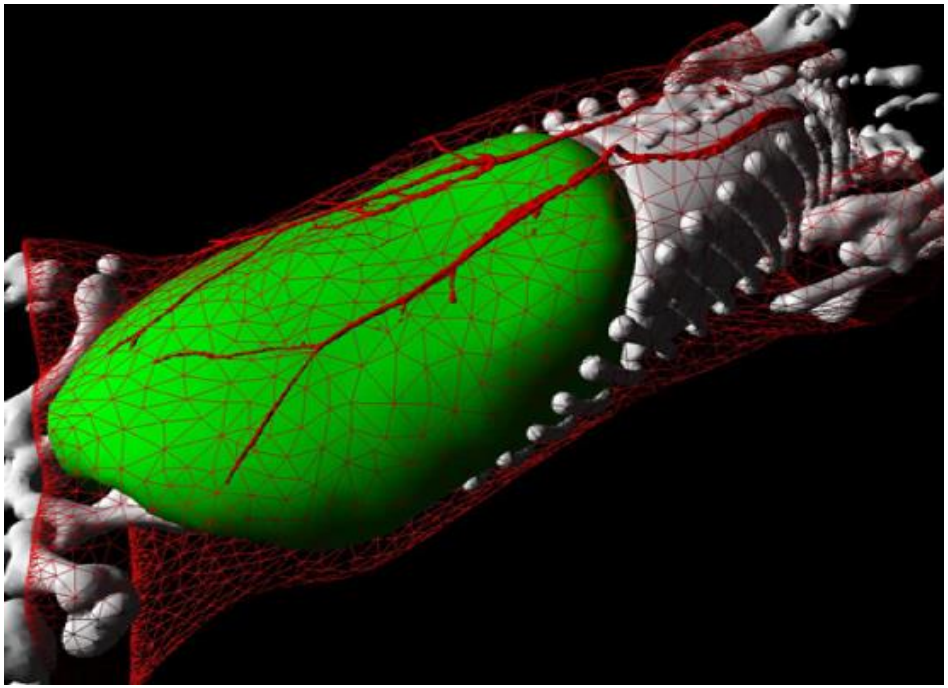


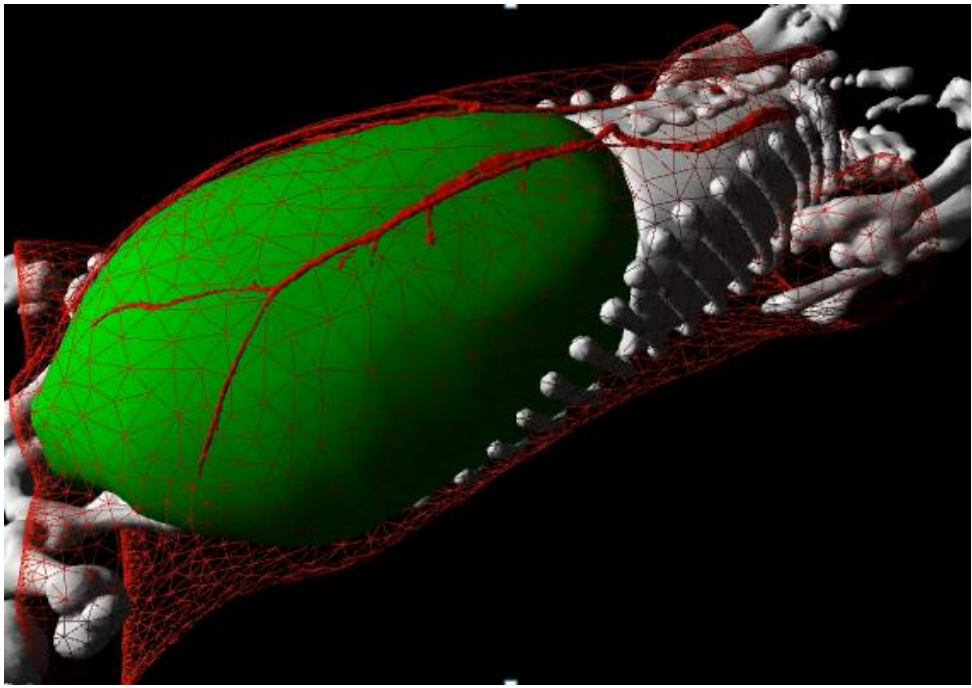
Before

After

Error on main arteries < 1 mm (real-time)

Step 2 : Pneumo-peritoneum simulation





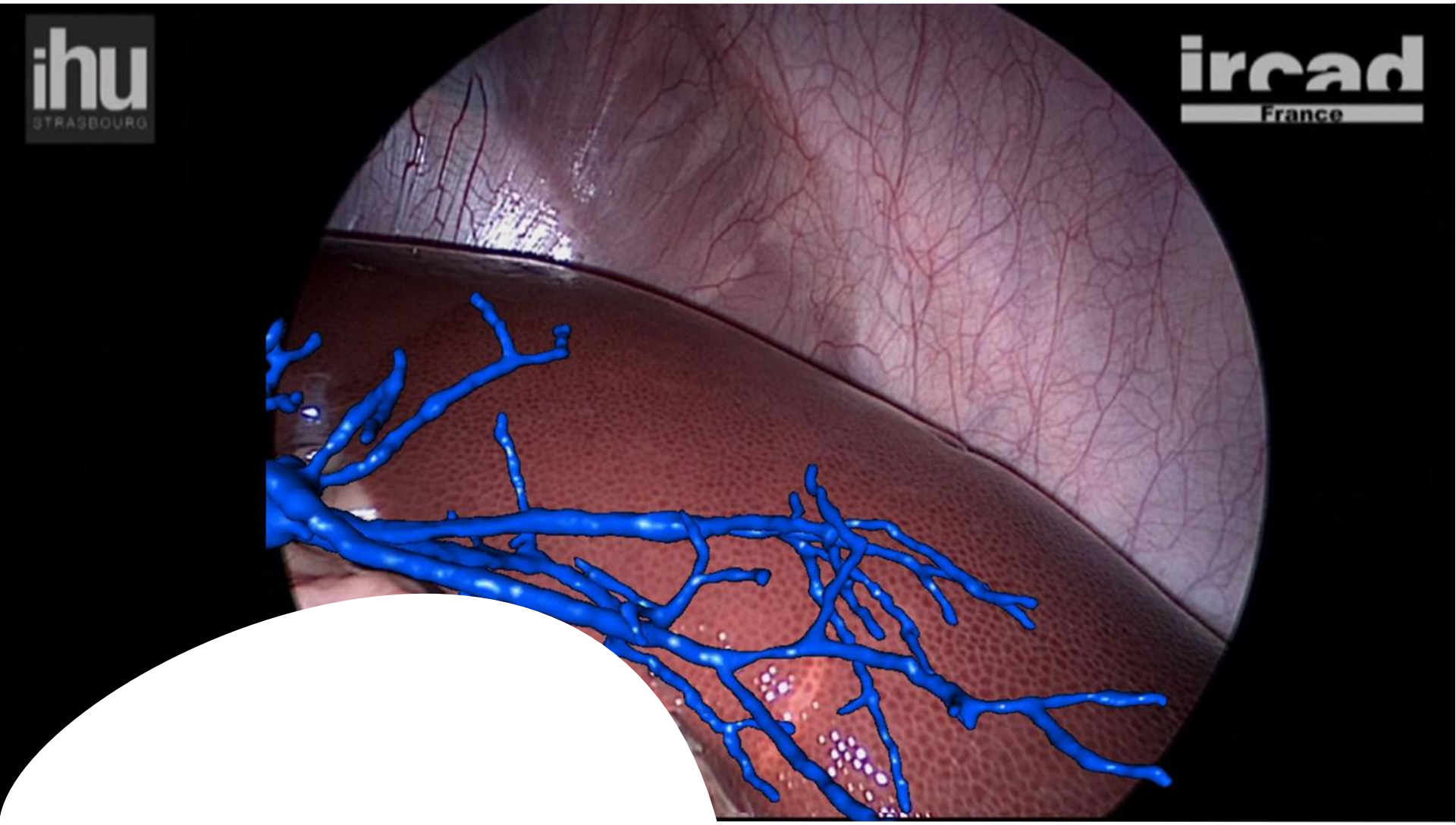
Simulation of Pneumoperitoneum for Laparoscopic Surgery Planning
Bano et al. , MICCAI 2012

Step 3: Surgical Table displacement

CT or MRI preop position ≠ OP-room position

Pneumoperitoneum + Table displacement changes organ positions

Step 3 : Automatic Registration Zeego



IHU Lasar Project

Step 4 : Other trocard positionning

➔ Do not modify organs position

➔ Allows for surgical instruments introduction

Need : Recognition and Tools tracking

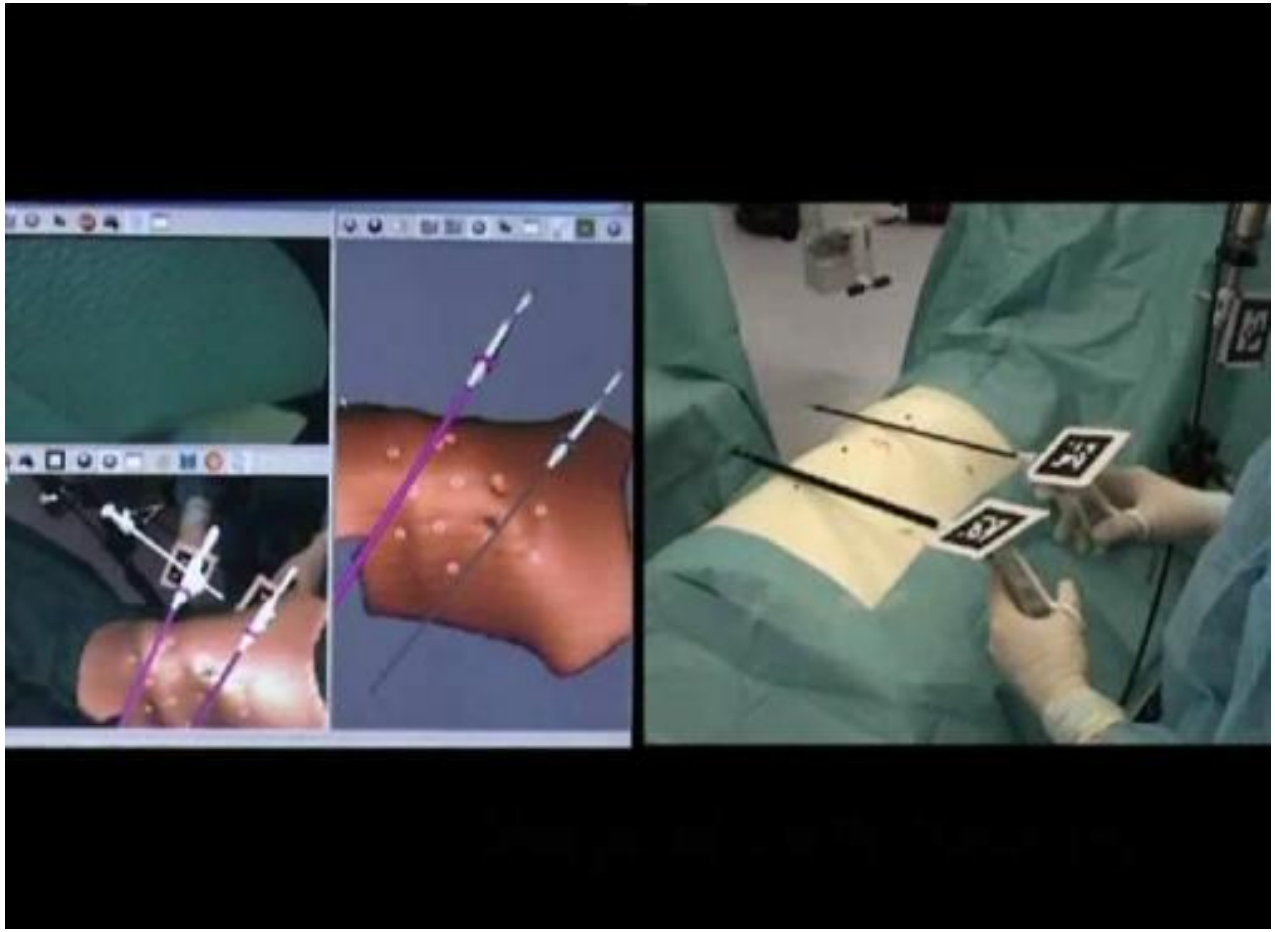
Step 4 : Tools Recognition & Tracking

➔ Optical tracking

Most frequent system

Step 4 : Tools Recognition & Tracking

➔ AR-Tag Optical tracking

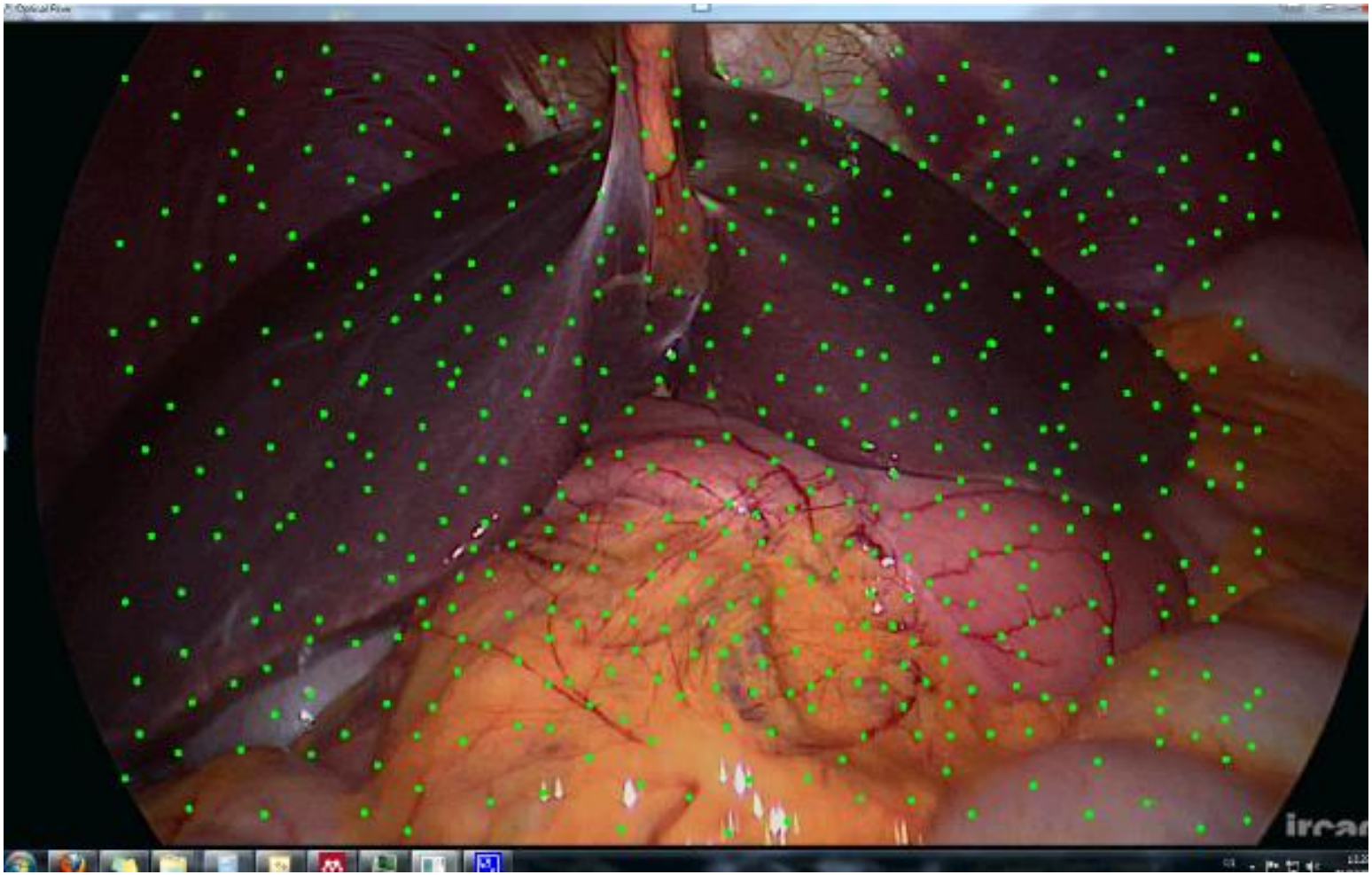


Based on normal camera

Step 5: Laparoscopic exploration

Step 5 : Laparoscopic Exploration

Feature Tracking : no need of optical tracking



Step 5 : Laparoscopic Exploration

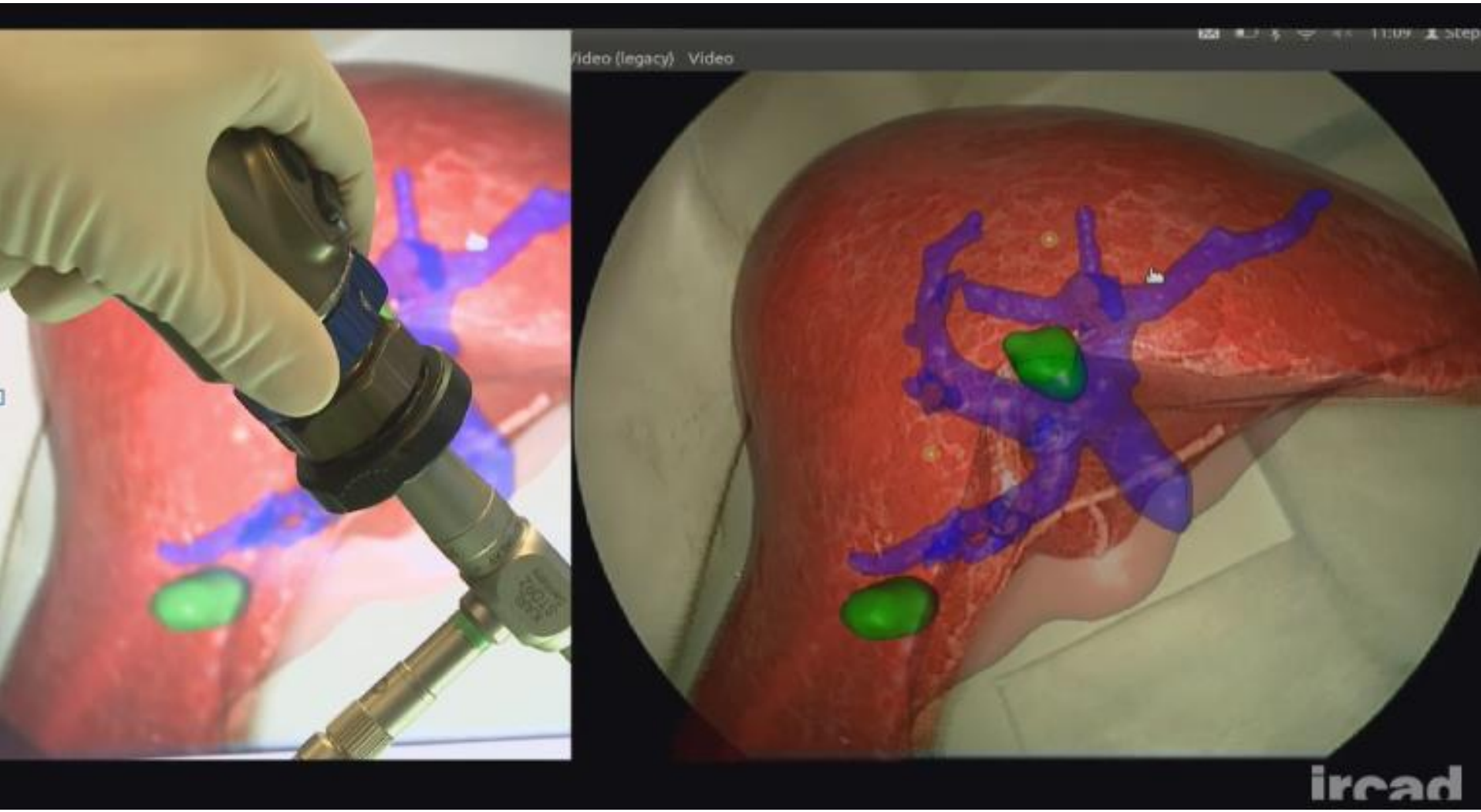
Feature Tracking

Improvement of classical method over 300%

Performance evaluation of simultaneous RGB analysis for feature detection and tracking in endoscopic images

Selka et al., Medical Image Understanding and Analysis 2012

Step 5 : Laparoscopic Exploration



Feature Tracking application to automated AR

Step 5 : Laparoscopic Exploration

Feature Tracking application to automated AR

Step 5 : Laparoscopic Exploration

Feature Tracking + Real-time Registered Simulation

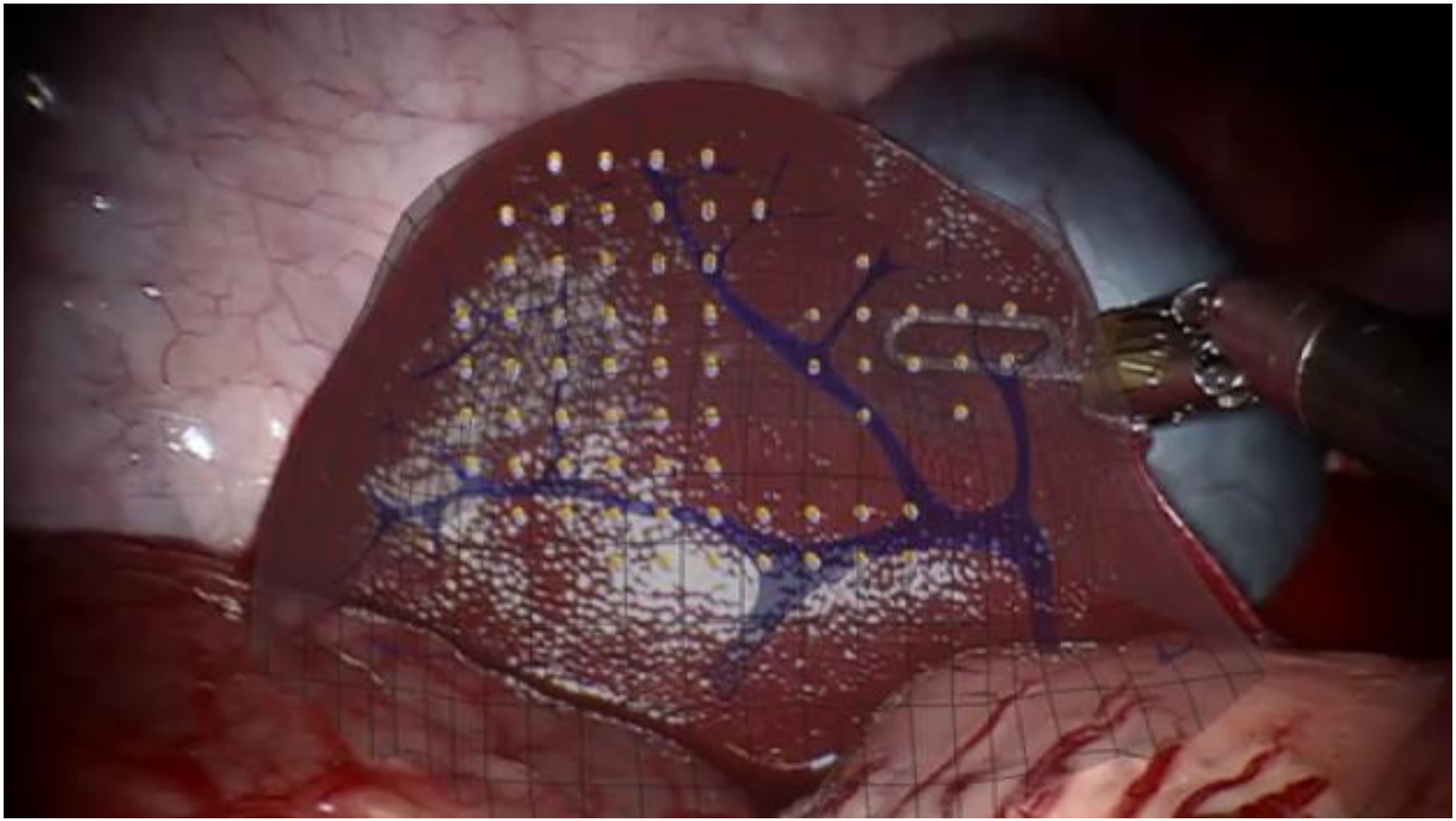
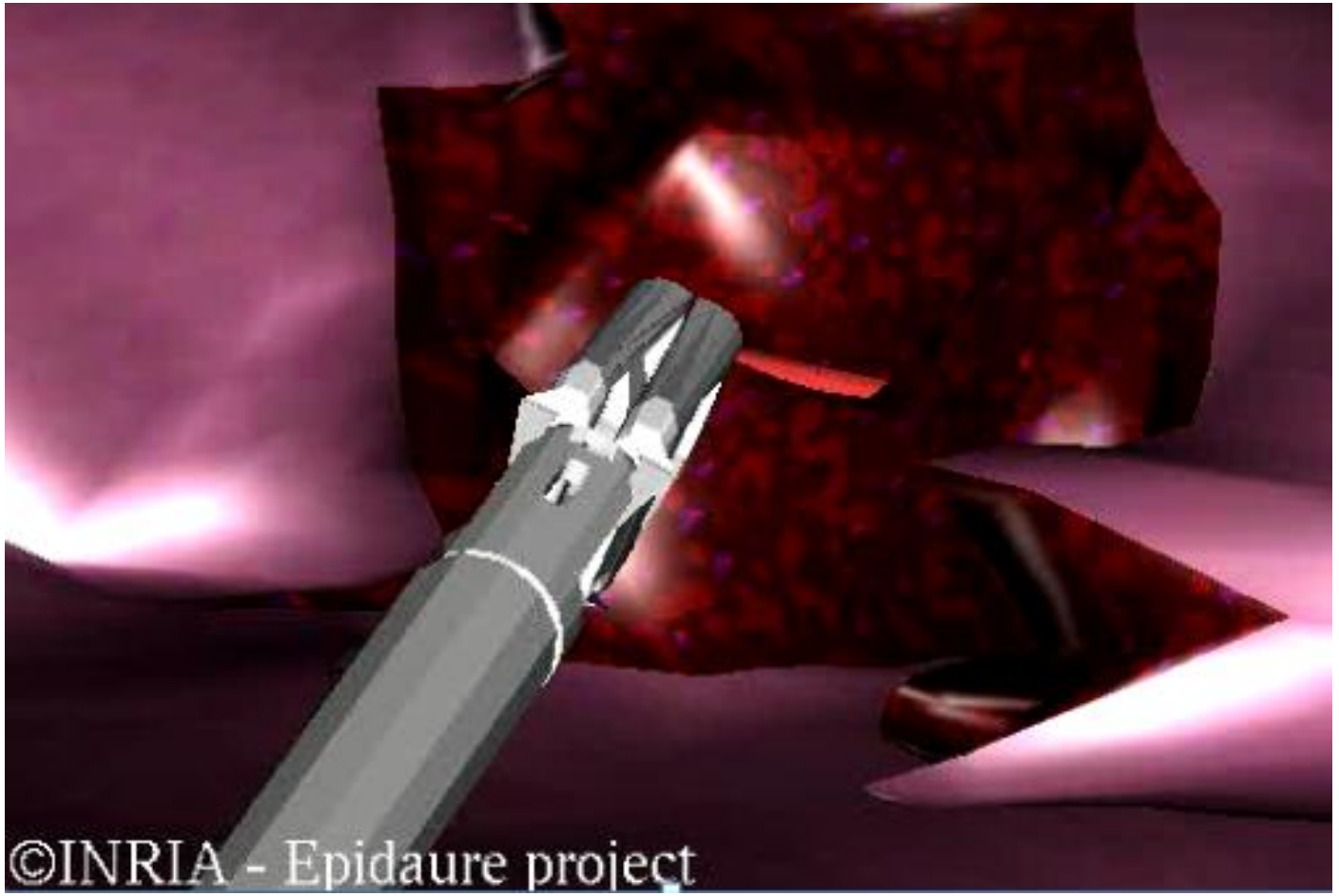


Image-guided Simulation of Heterogeneous Tissue Deformation For Augmented Reality during Hepatic Surgery, Haouchine et al., *ISMAR 2013*

Step 6 : Removal of liver links
Step 7: And Hile vessels control

Step 8 : Liver Resection

Real-time Registered Simulation



IHU – IRCAD : R&D Objectives

Robotics & Automation

Develop optimized robots

What is the best solution to clean an house floor ?

Biggest but technological demonstration more sexy

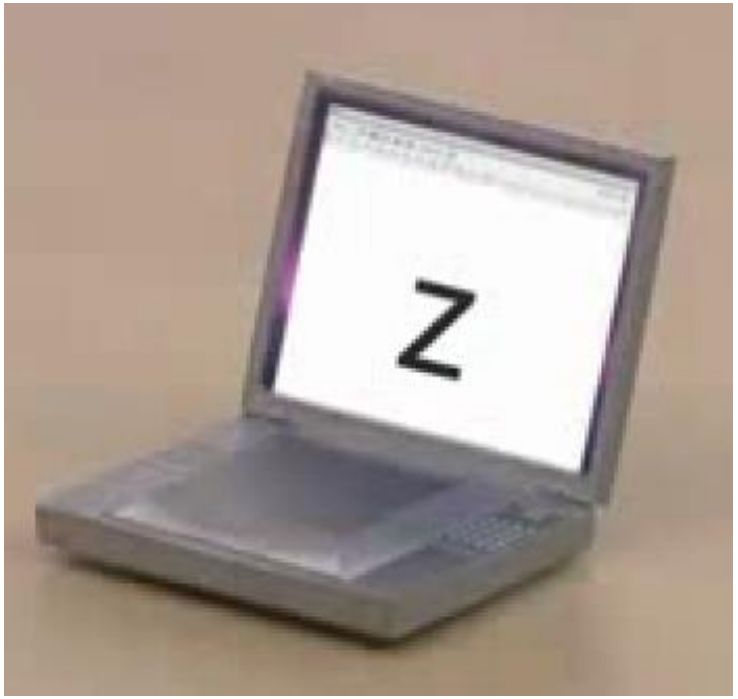
Develop optimized robots

What is the best solution to clean an house floor ?

Biggest but technological demonstration more sexy

Develop optimized robots

The most important is not the size
but the efficiency to reach the objective



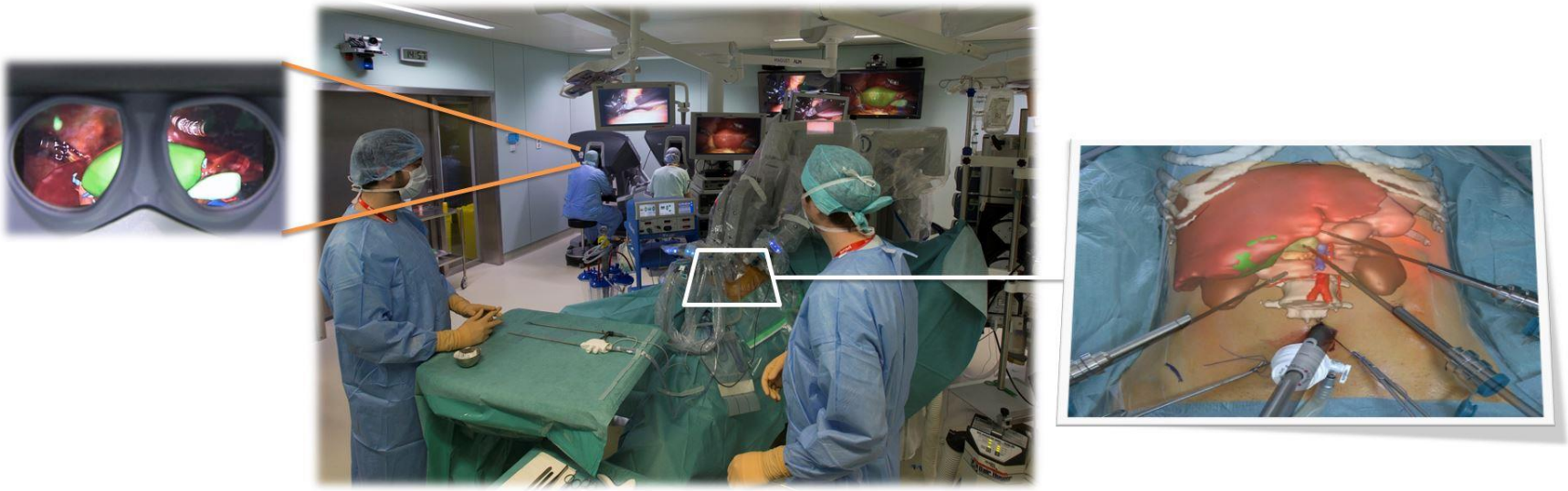
Develop optimized robots

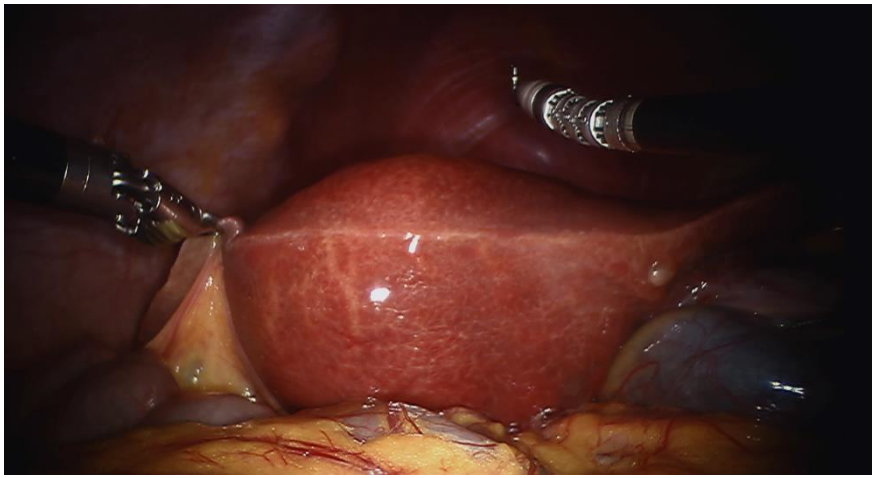
What is the best solution for Abdominal Surgery ?

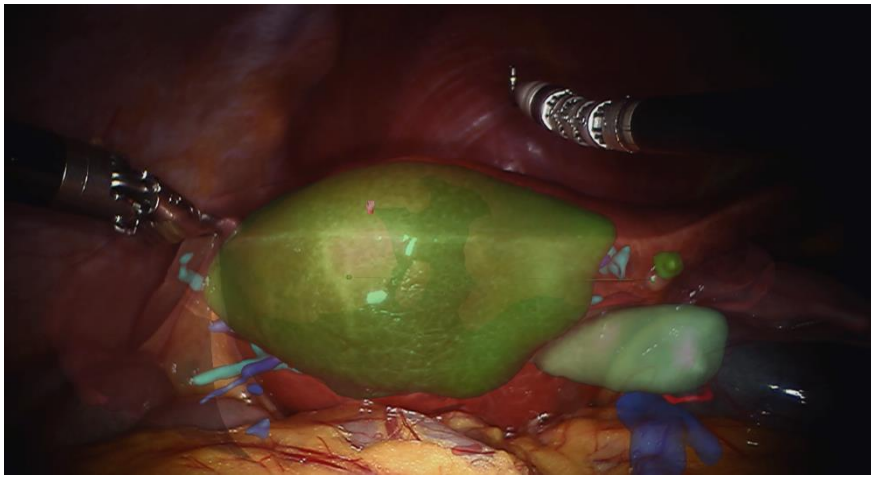
Large Robot, several incision,
Limited Patient access,
But Precise and Robust
Commercial success

Small Robot, 1 incision,
Large Patient access,
But Less Precise and less Robust
Not Commercialized yet

Interactive Augmented Reality







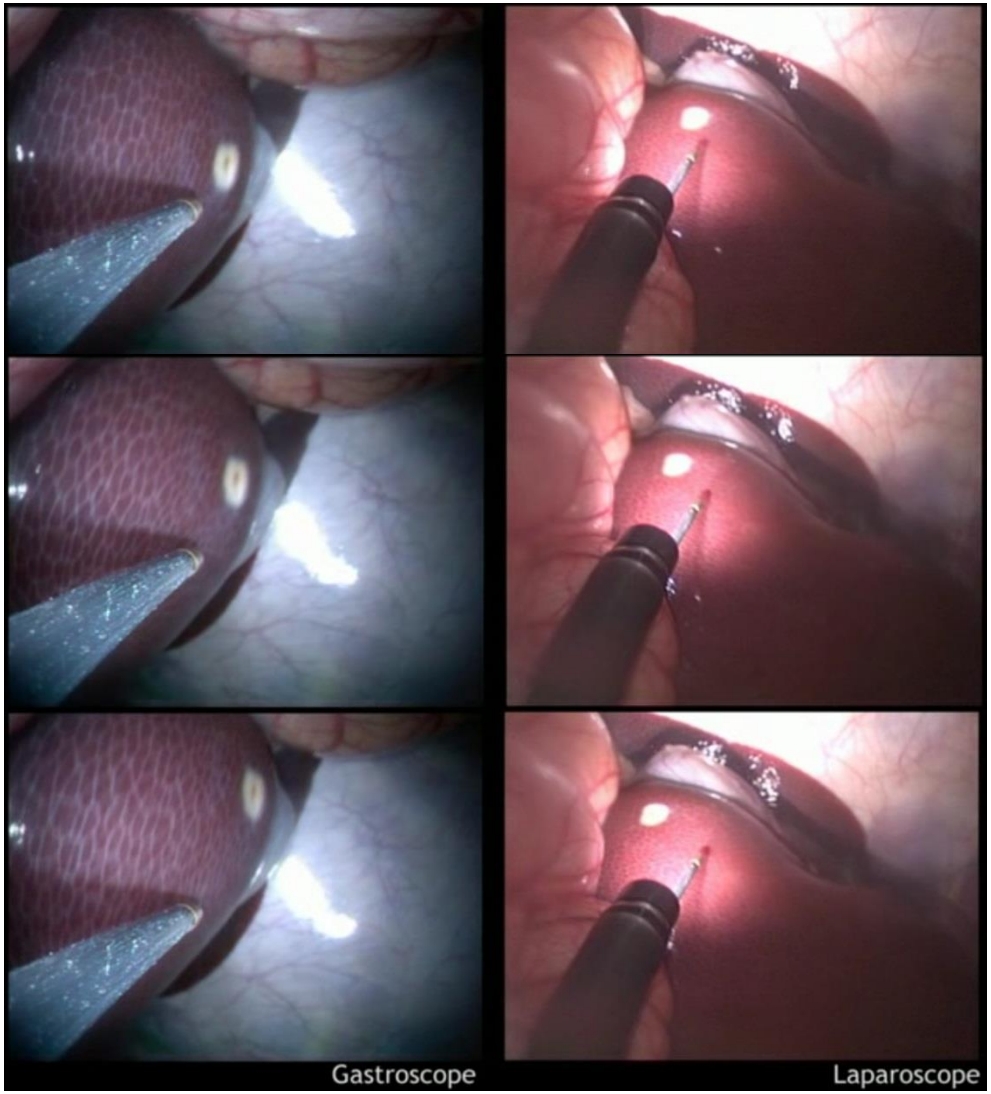
Robotic Liver Surgery, AR-Surg©IRCAD

Augmented Reality + Fluorescence

Robotic Liver Surgery, AR-Surg©IRCAD

Next Step: Automatic Movement filter

Operative vision of the flexible endoscope

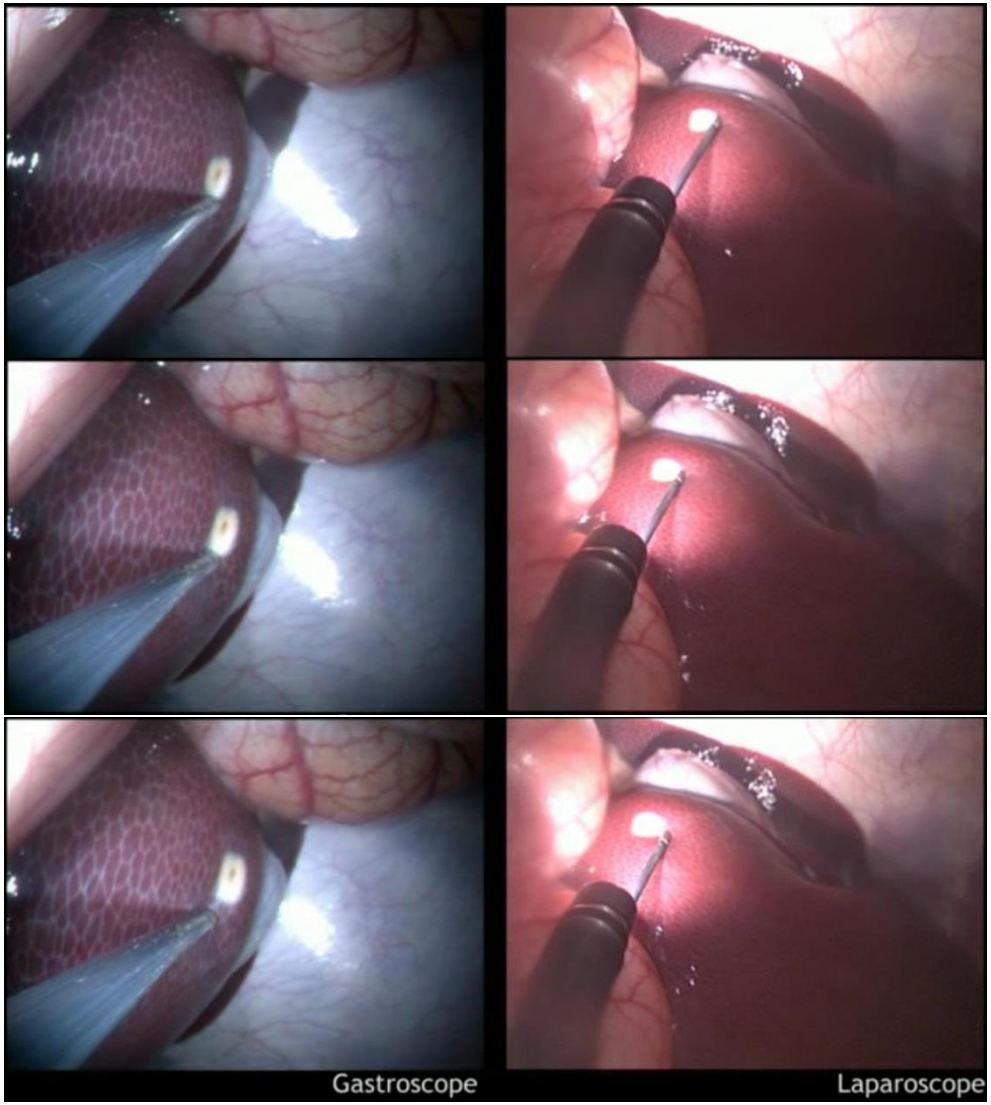


Laparoscopic view showing that the endoscope do not follow breathing movements

Without the robotized system

Next Step: Automatic Movement filter

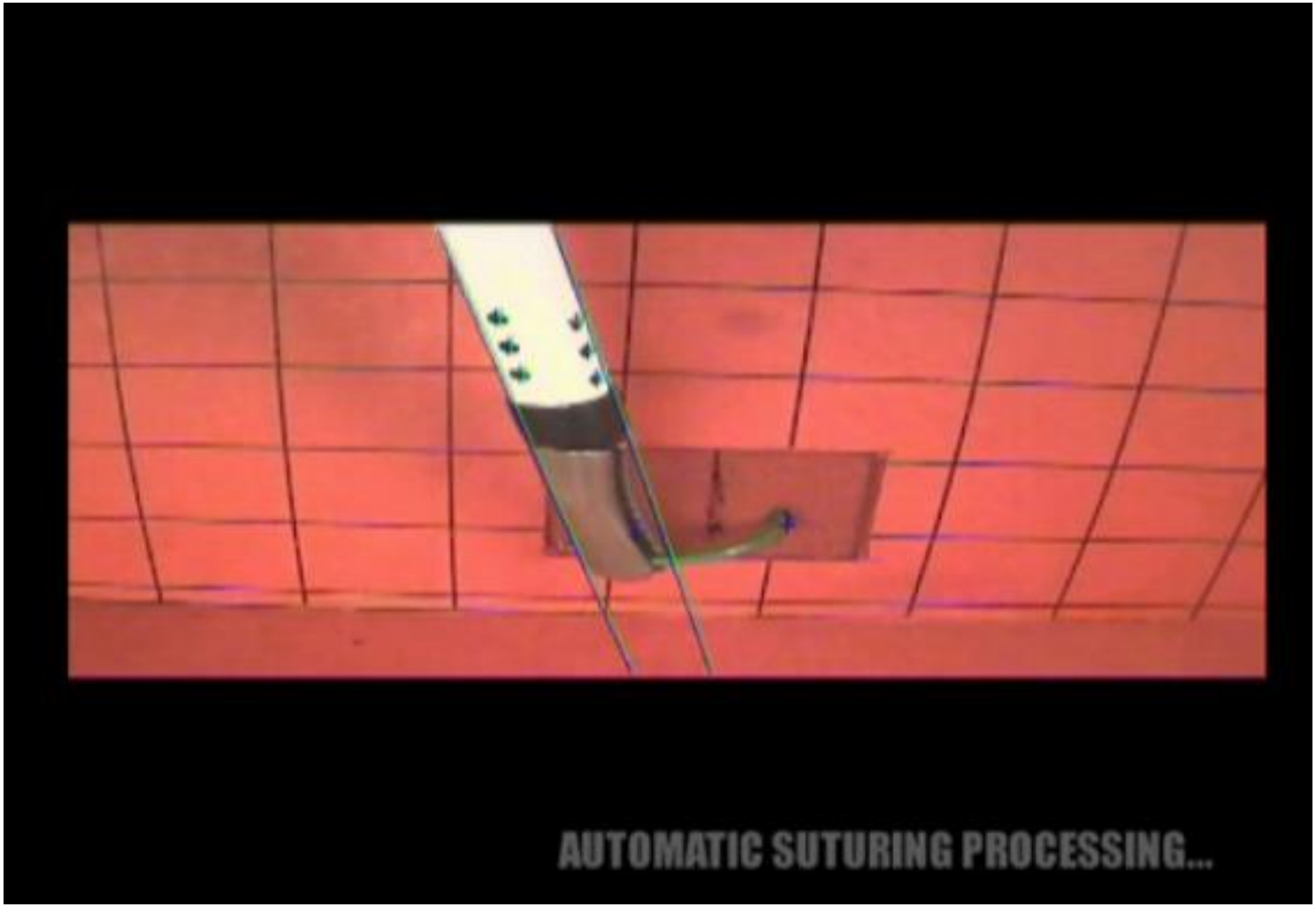
Operative vision of the flexible endoscope: Target is always at the center of the image.



Laparoscopic view showing that the endoscope follows breathing movements

With the robotized system

Next Step : Automatic Driving



Conclusion

Future of Surgery will be Image Guided

Future Hybride OP-Room

Conclusion

Computer assistance must :

- Improve the usual procedure
- Propose Easy to use solutions
- Follow the Surgical Workflow
- Provide more safety to patient
- Reduce Human error through accurate automation

Future Hybride OP-Room

CONCLUSION

Research & innovation in medicine is for human like the walk for a baby: It's a non reversible need to stand up to be alive, despite the inevitable falls punctuating his quest.

Prof. Luc Soler

IRCAD-IHU R&D Director

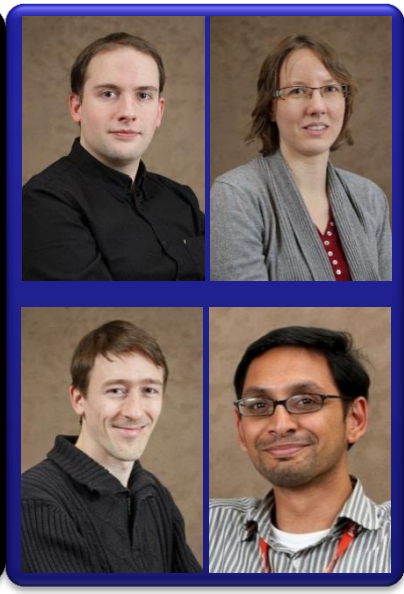
CONCLUSION

Do not be affraid by fall, but fear to never stand up !

Prof. Luc Soler

IRCAD-IHU R&D Director

Thanks for your attention



R&D IRCAD France

IHU R&D