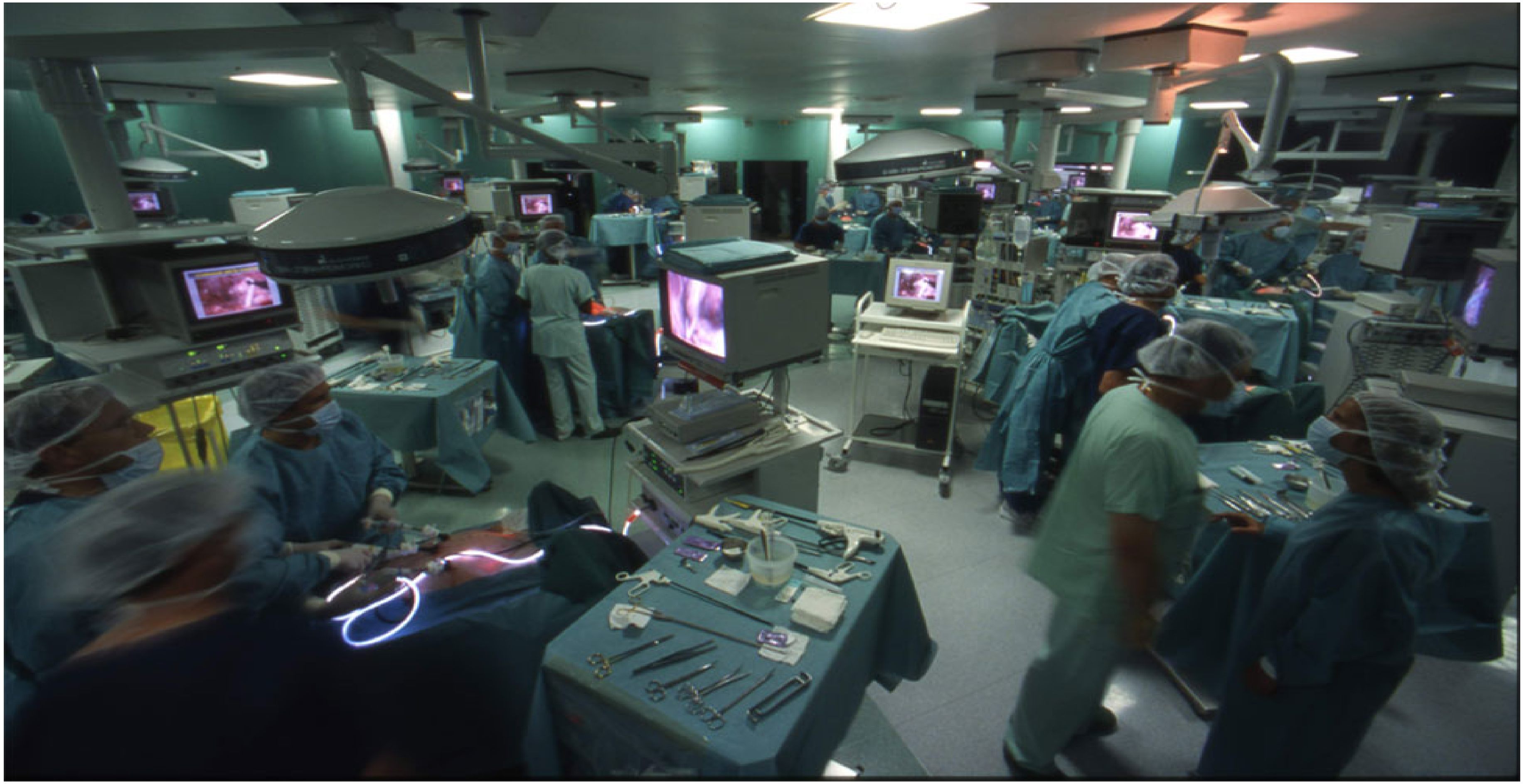
Virtual Reality and Robotics in Digestive Surgery



Pr. Luc Soler, Pr. Jacques Marescaux

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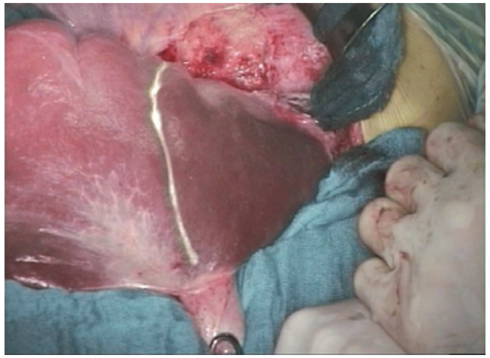
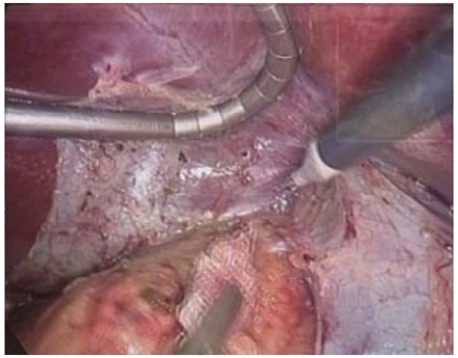
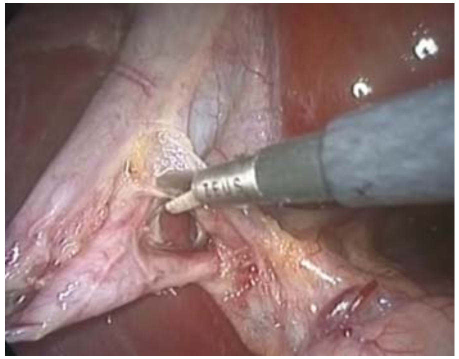
20th century Surgical Evolution

Open → Laparoscopy → Robotics







New vision of surgery

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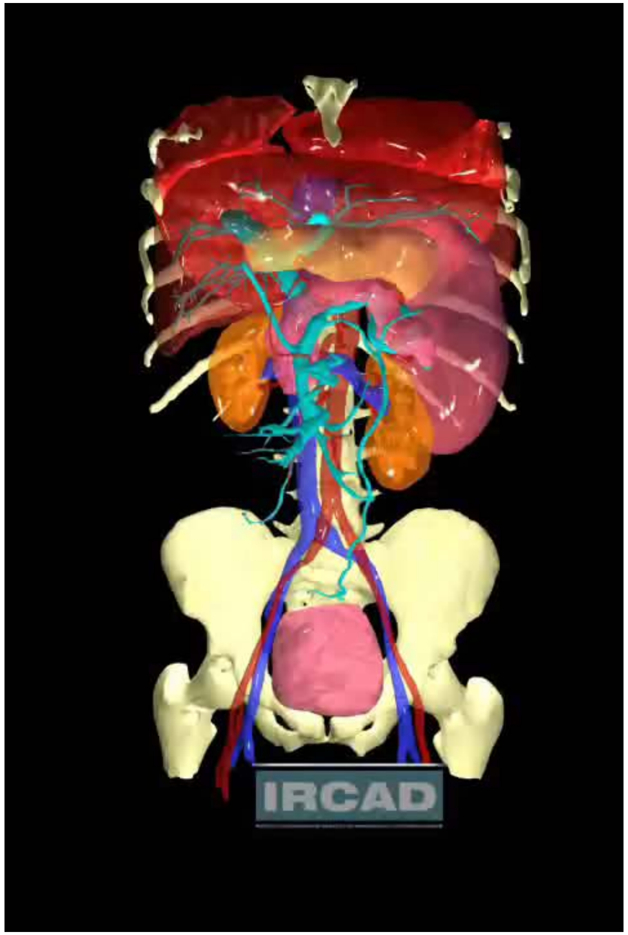
WebSurg : Continuous education

Totally FREE !…

20th century Imaging revolution

2D slices → 3D virtual patient



New vision of the patient

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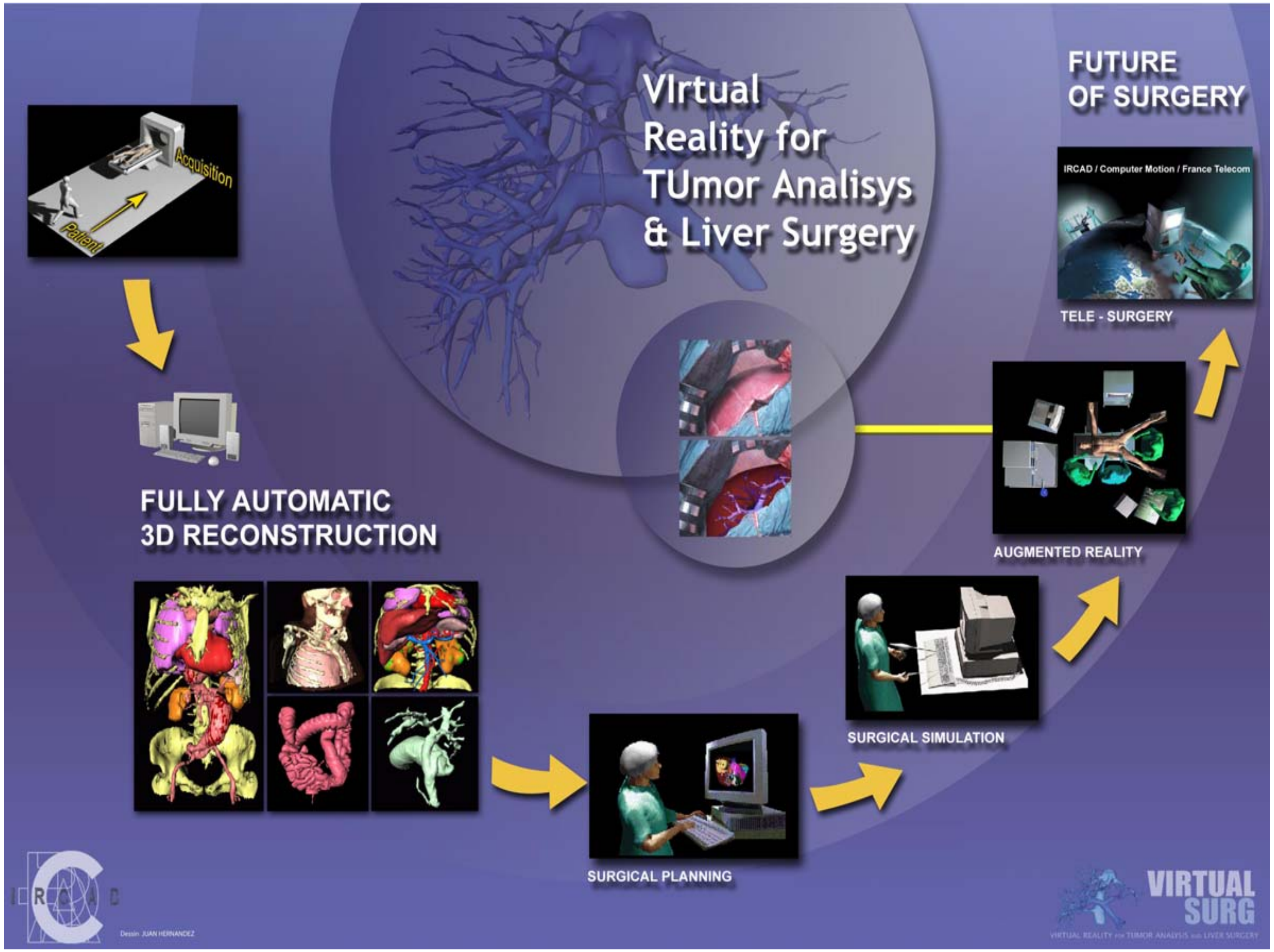
A global approach



From Image to Computer assisted Surgery

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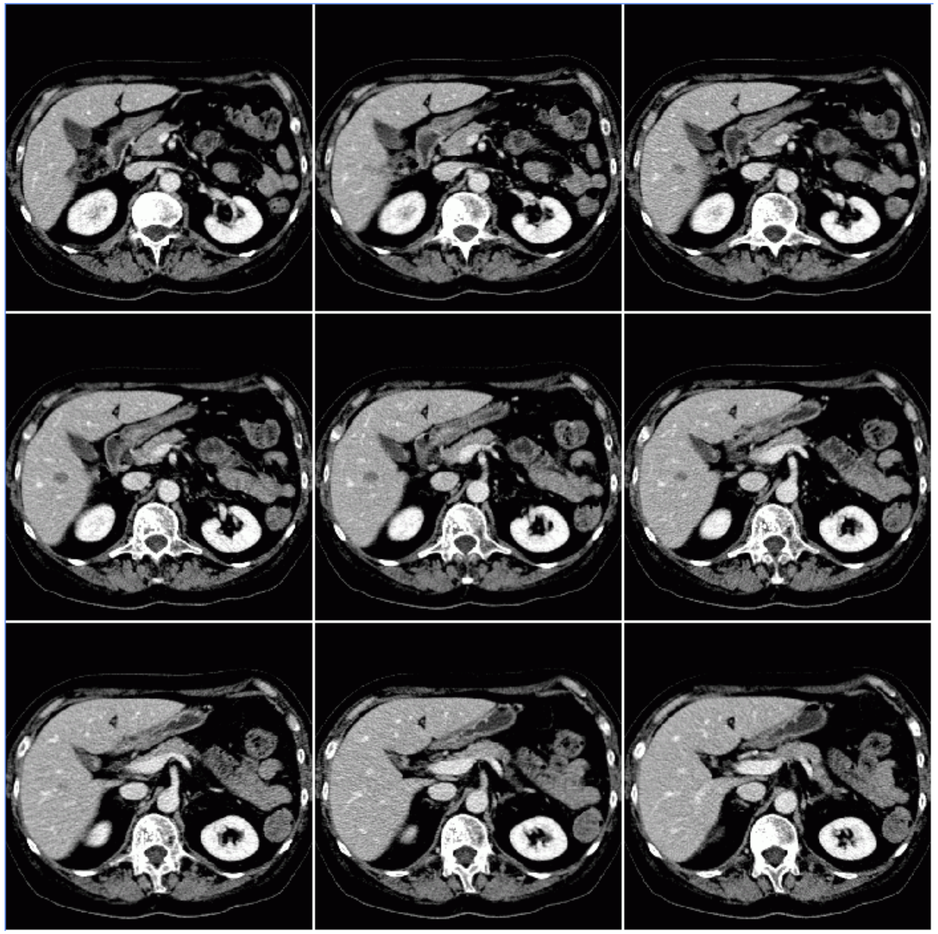
First Step : 3D Modeling of patient

From CT-scan or MRI of a patient



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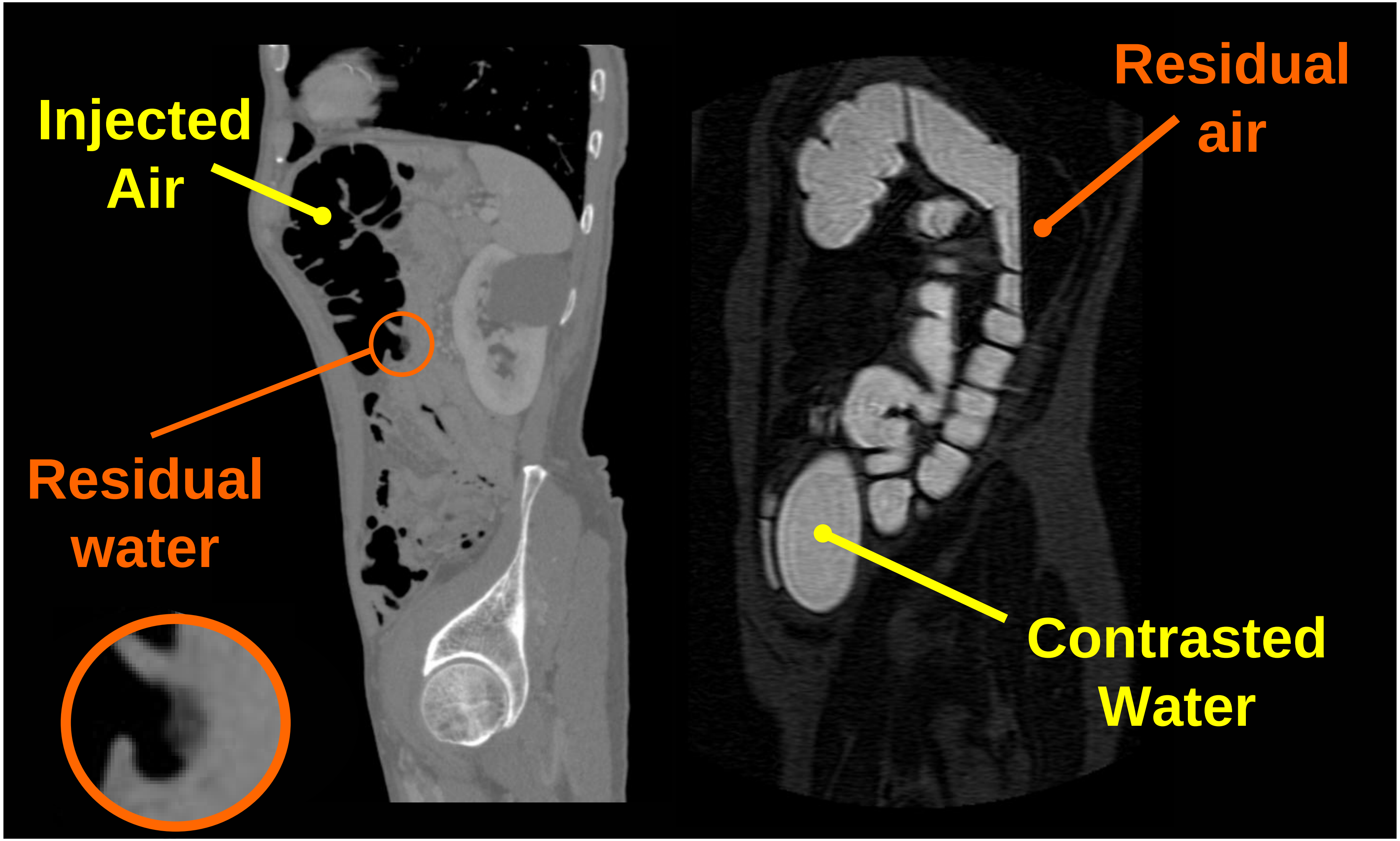
First Step : 3D Modeling of patient



CT-Scan or MRI

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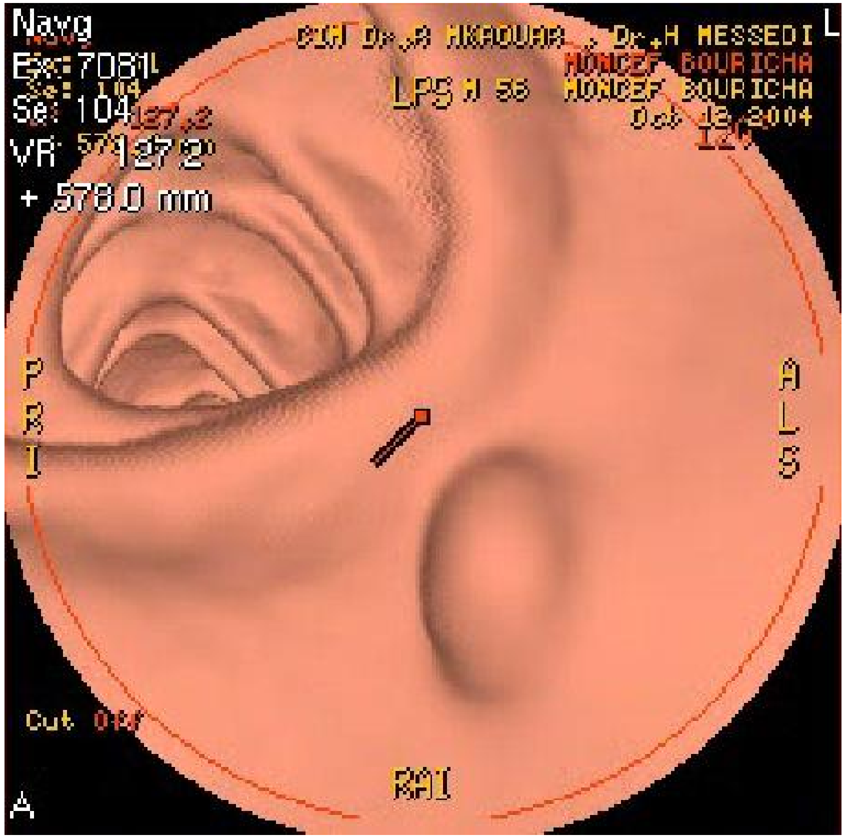
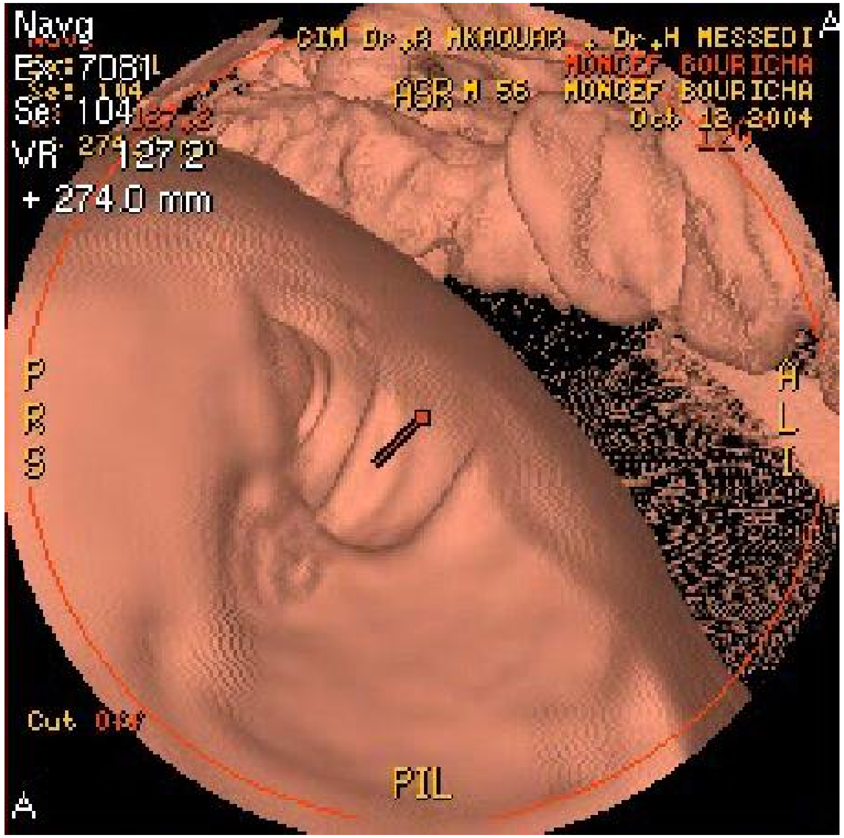
Ray Tracing : Virtual navigation

Nice 3D vision, but no real delineation
Quality depends of good parameterization

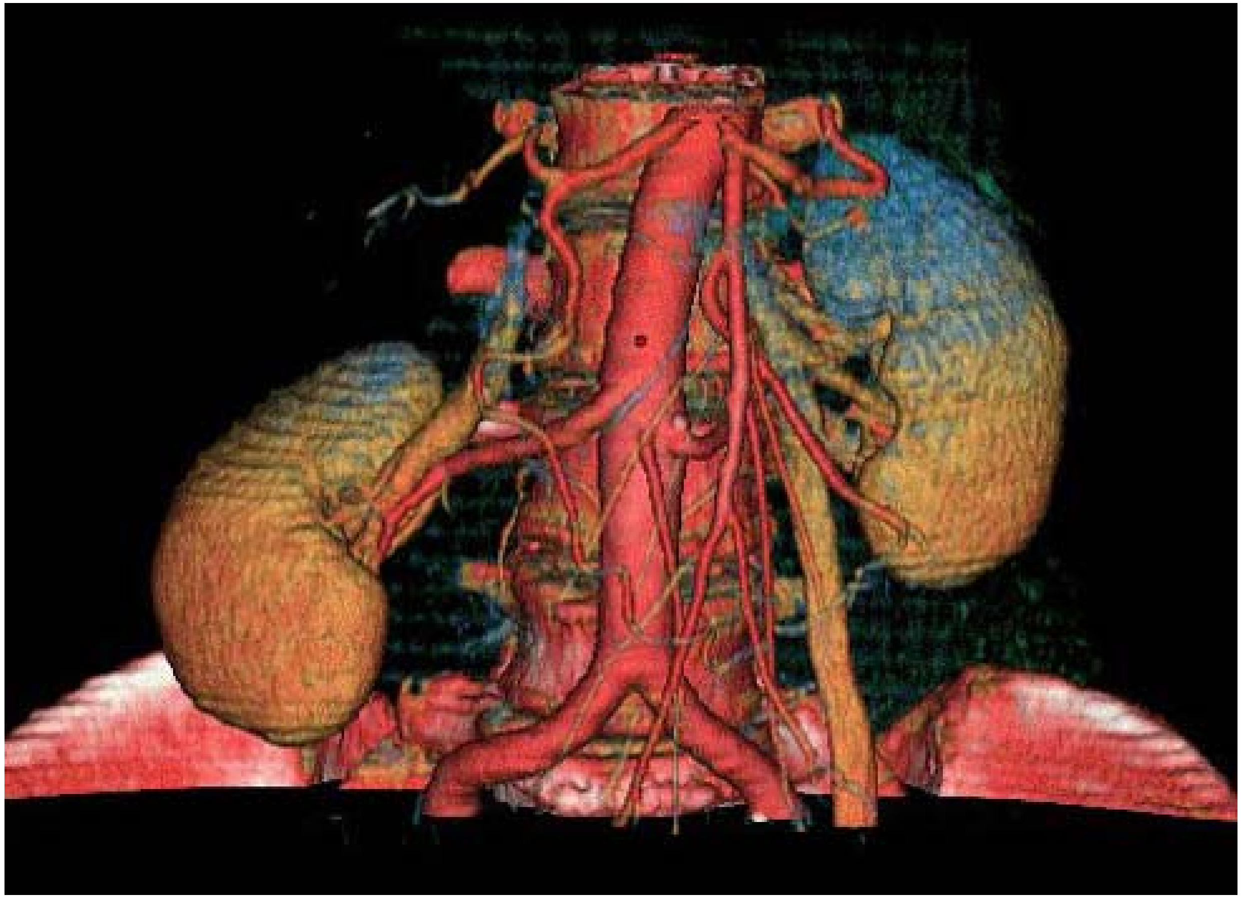




Ray Tracing Limited to lumen vision

Volume Rendering : vessels in 3D

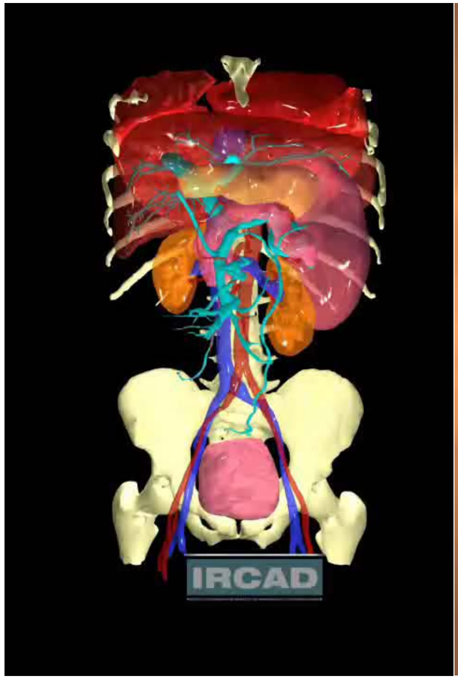
Transparency of voxels without Delineation of Structures

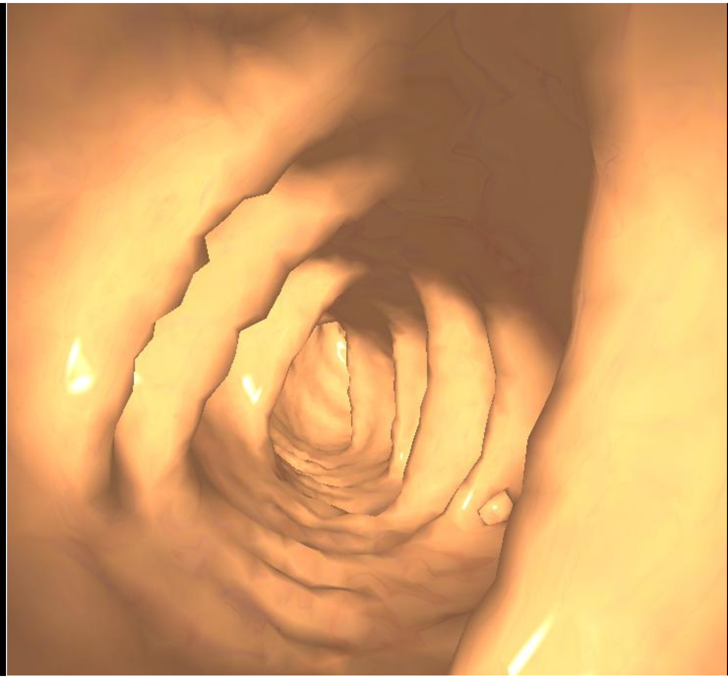
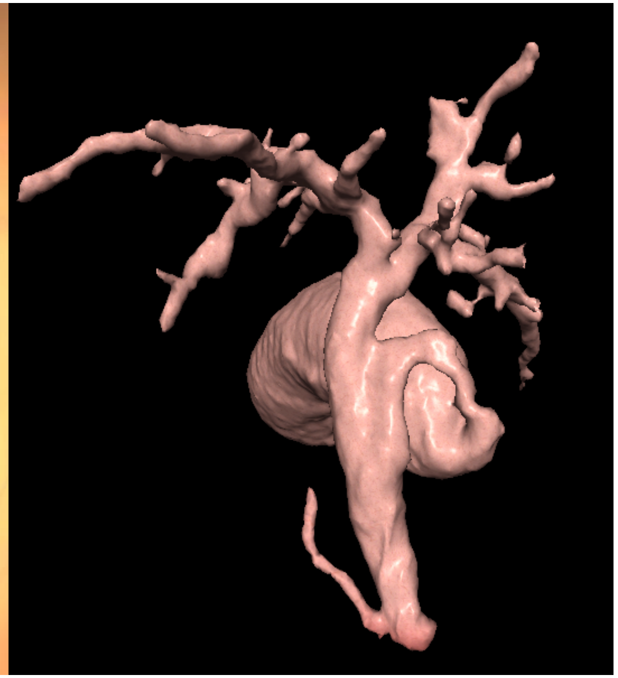


Volume rendering   Limited to 3D visualization

Surface Rendering

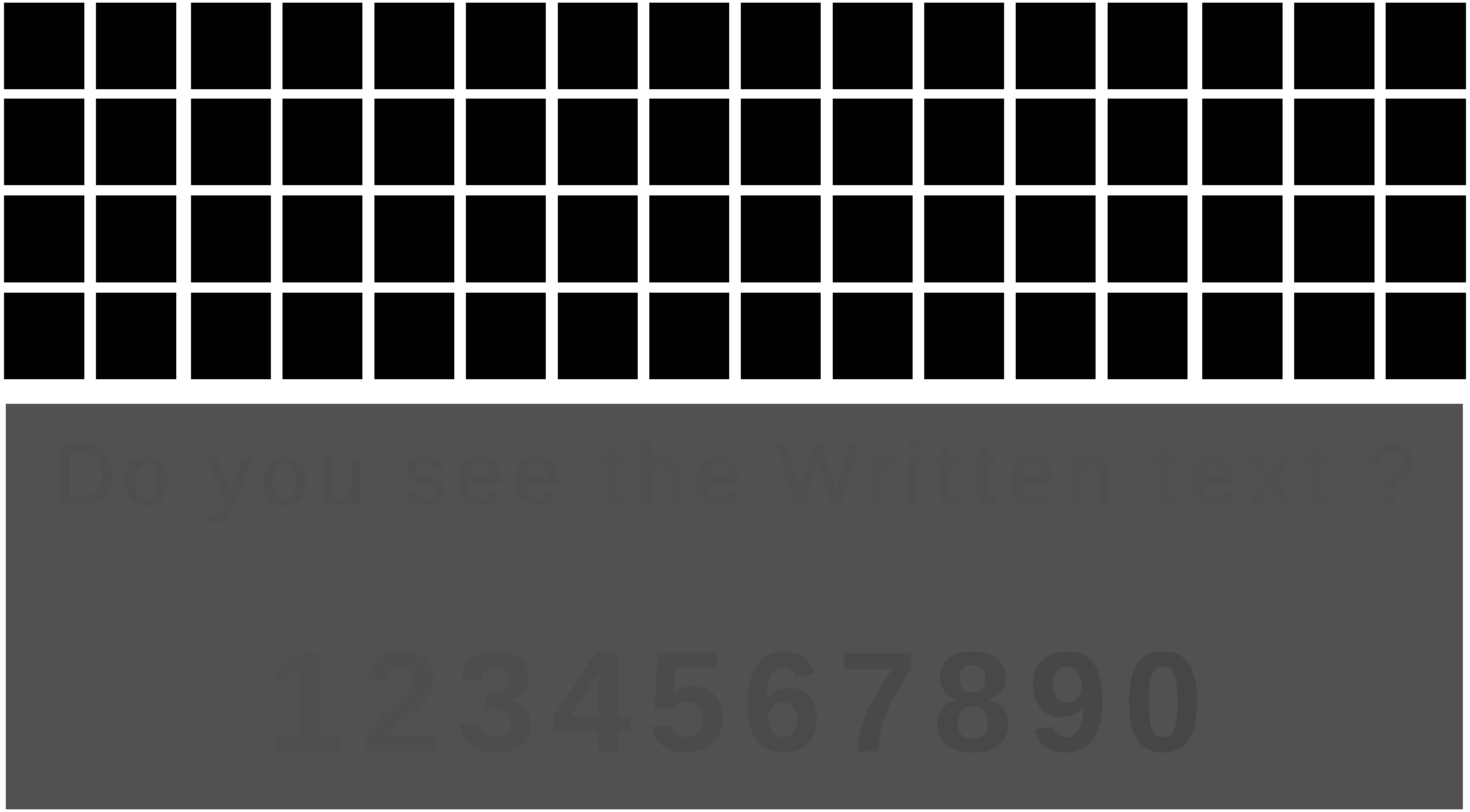
- Need a real delineation of each Structure
- Allows efficient internal and external views
- Can be visualized with any Internet Explorer



First Step : 3D Modeling of patient

Human limit → Our vision



Only 16 perceptible contrasts

First Step : 3D Modeling of patient

Human Advantage → Our intelligence

Yuo Sholud arirve to raed tihs txet eevn if thier is sevreal invresoin of letetrs due to Yuor wodnerflul brian

Vuos devirez pavrenir à lrie ce tetxe mmêe s'li y a queqlues invesrion de letetres, gârce à vorte mevreilluex cevreau.

First Step : 3D Modeling of patient

An expert system :

Translation of human knowledge

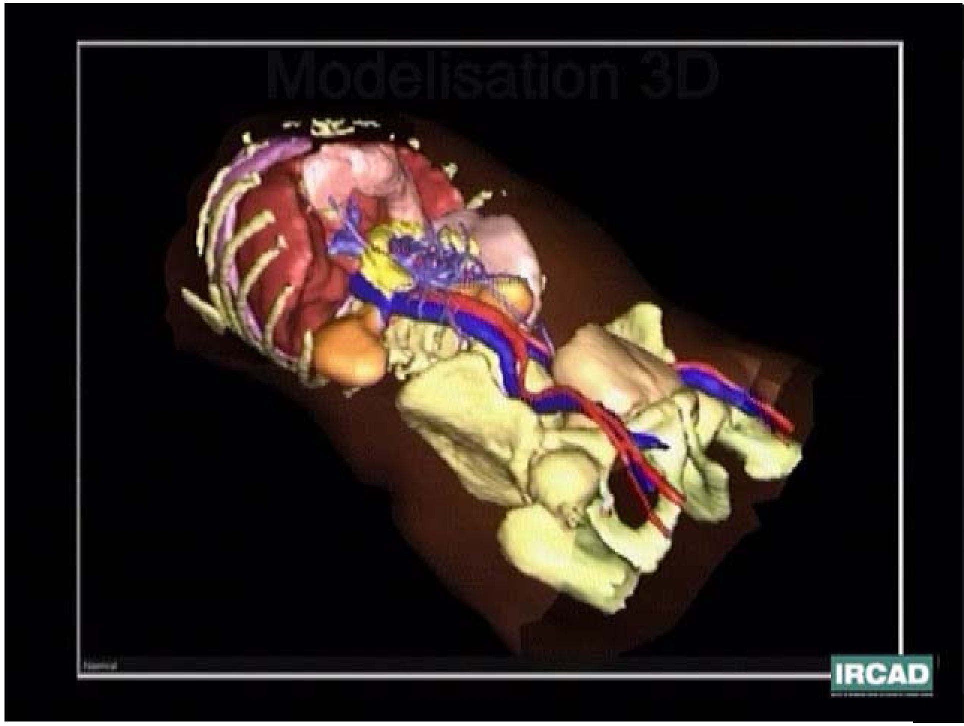
Density / Location / Shape / Topology

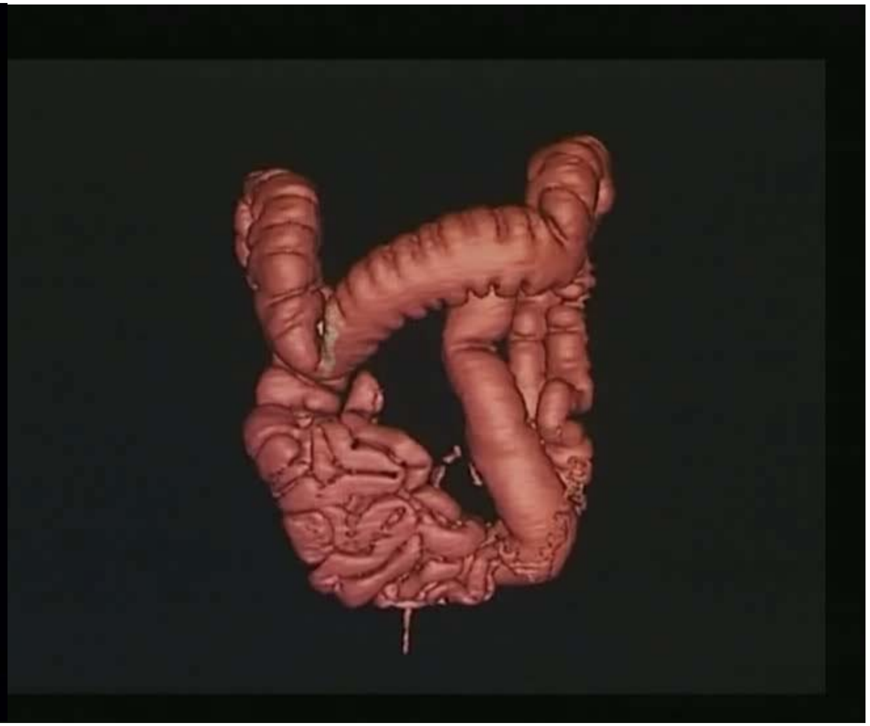
Density	Location	Shape	Topology
↓	↓	↓	↓
Thresholding Filtering Gradient	Distance Map and Constraints	Morphology +Geometrical Constraints	Topological Analysis & Constraints

First Step : 3D Modeling of patient

Automated delineation (15mn)

Liver area, colon, biliary tract, adrenal…

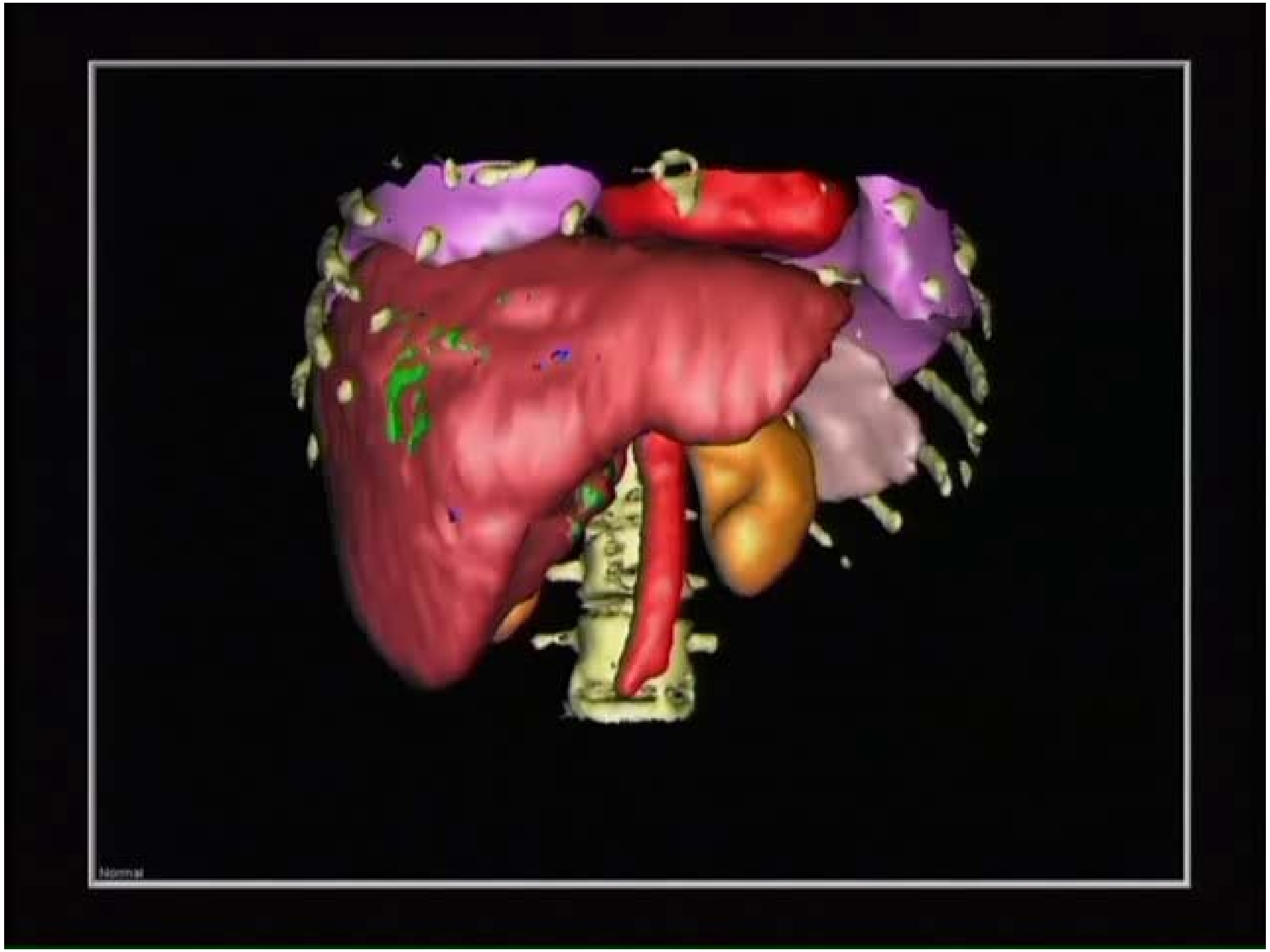




from CT-Scan ***or*** ***from MRI***

Surface Rendering **Visualization + Simulation**

First Step : 3D Modeling of patient



Used for liver surgery

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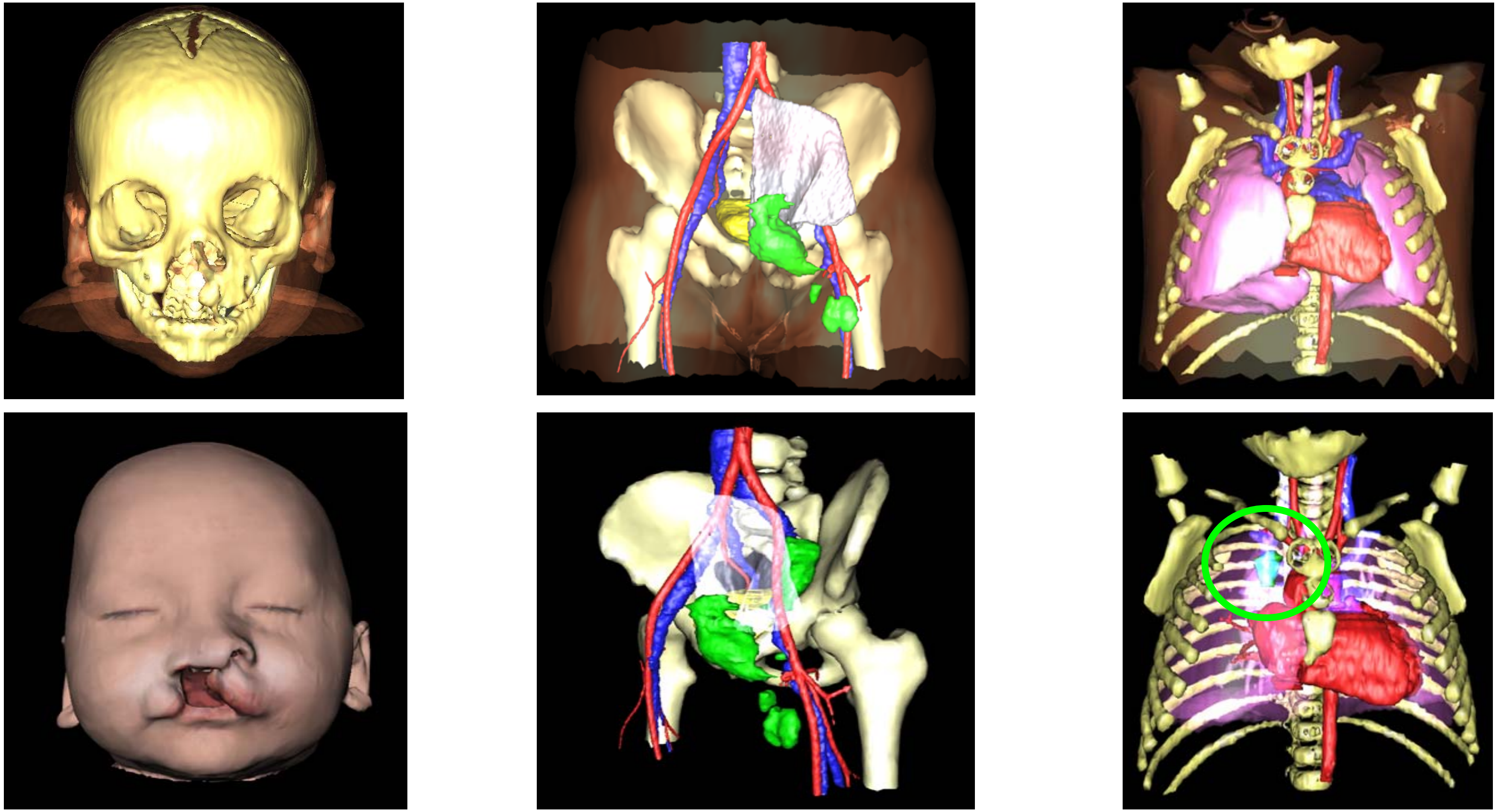
First Step : 3D Modeling of patient



Used for paediatric surgery

Limits …

Is Fully automation possible ?

No : It will always exist exception

but…

Main objective is essentially to provide a 3D modeling in a maximum of 15mn with a minimum of interactivity realized by a radiologist assistant and not a radiologist

Limits …

Is 3D Modeling in 15 mn feasible ?

Yes : but we need to improve segmentation software essentially for the most complex anatomical and pathological structures in the medical images.

Sample : stomac et pancreas in abdominal image of the liver

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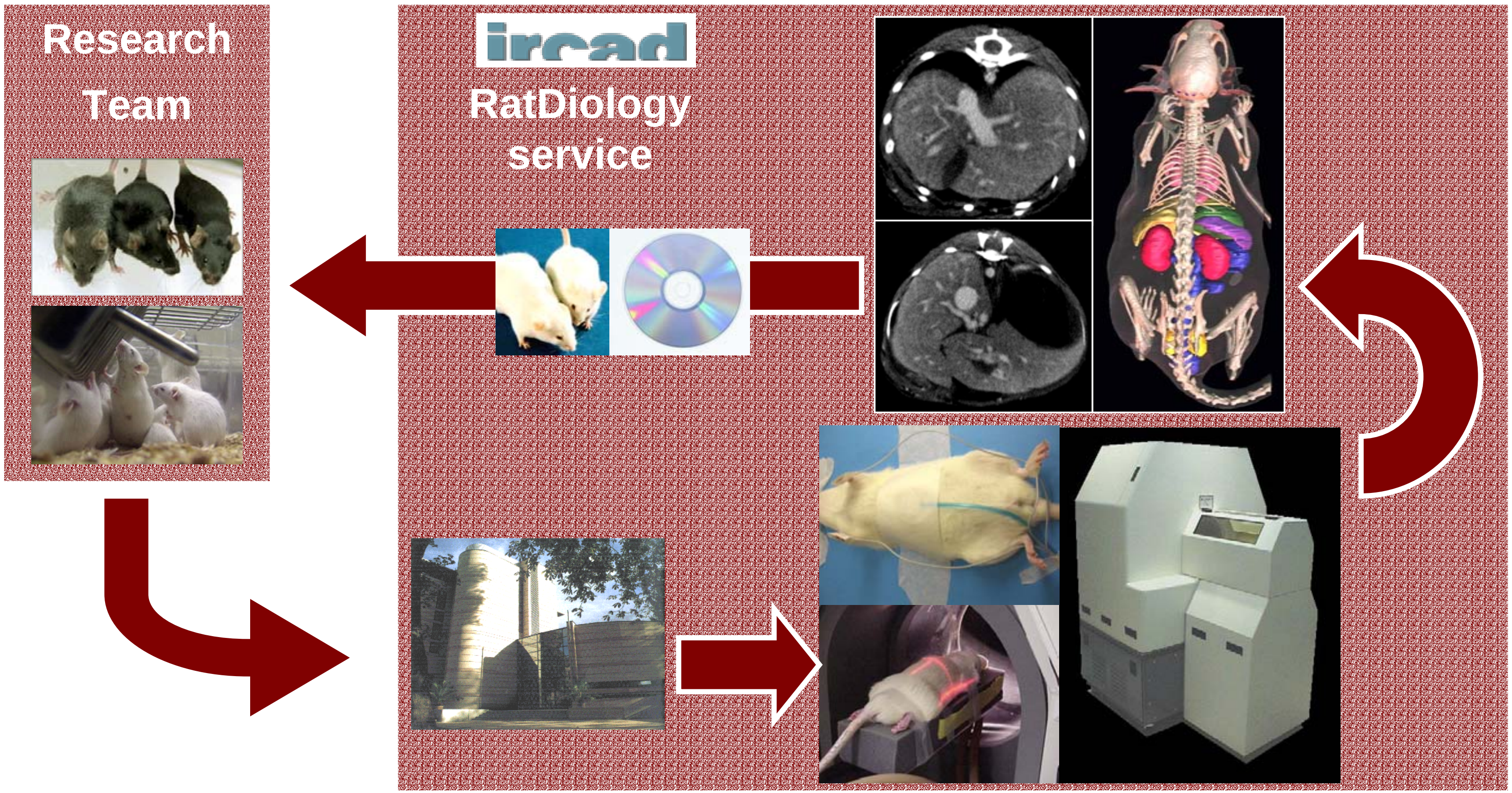
New tool for fundamental research

Provide a CT-scan imaging service for mice and rats including 3D modelling

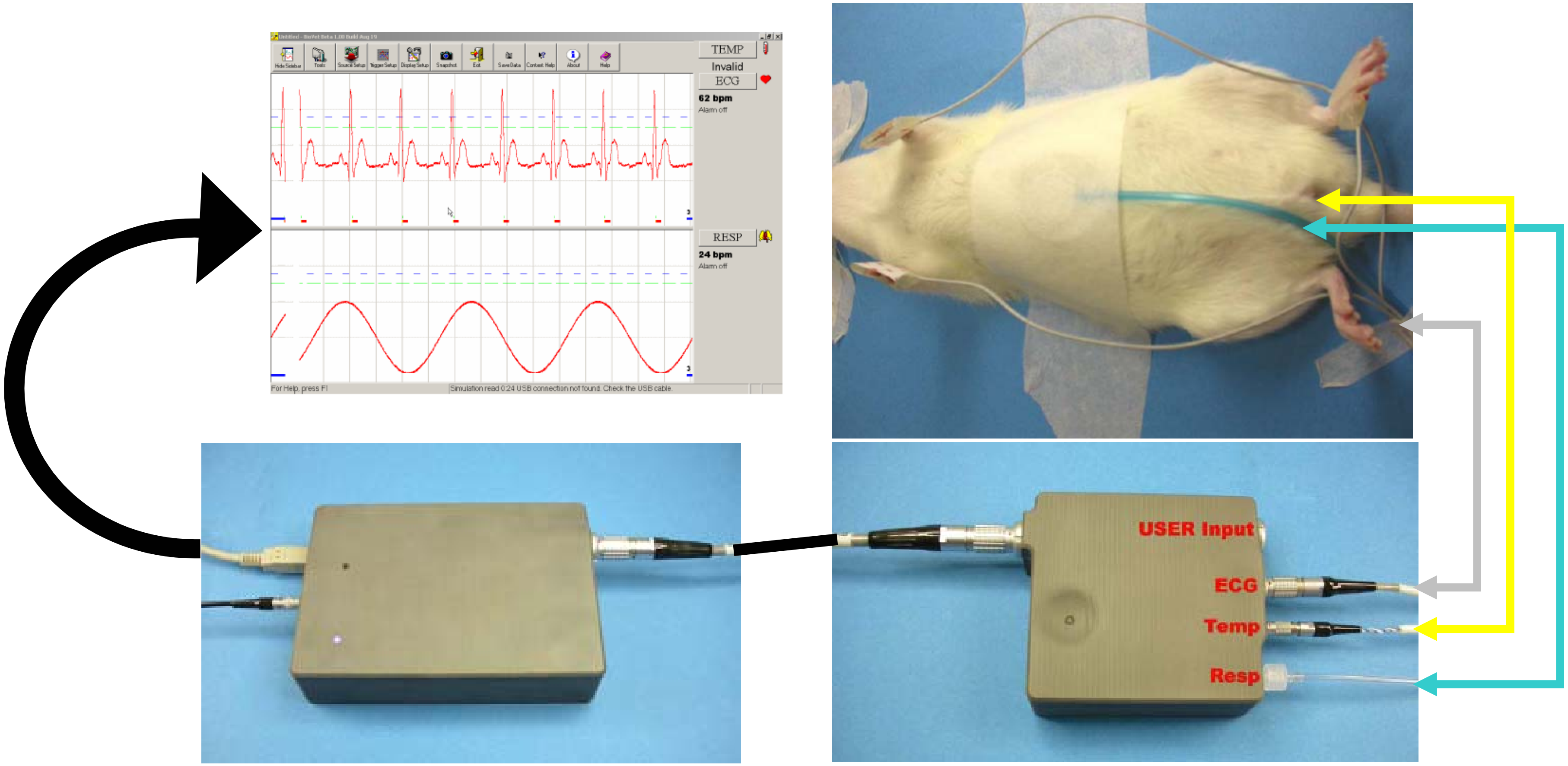


IRCAD's Micro CT-scanner

Région Alsace, Département Bas-Rhin, Ville de Strasbourg, Ligne Nationale contre le cancer

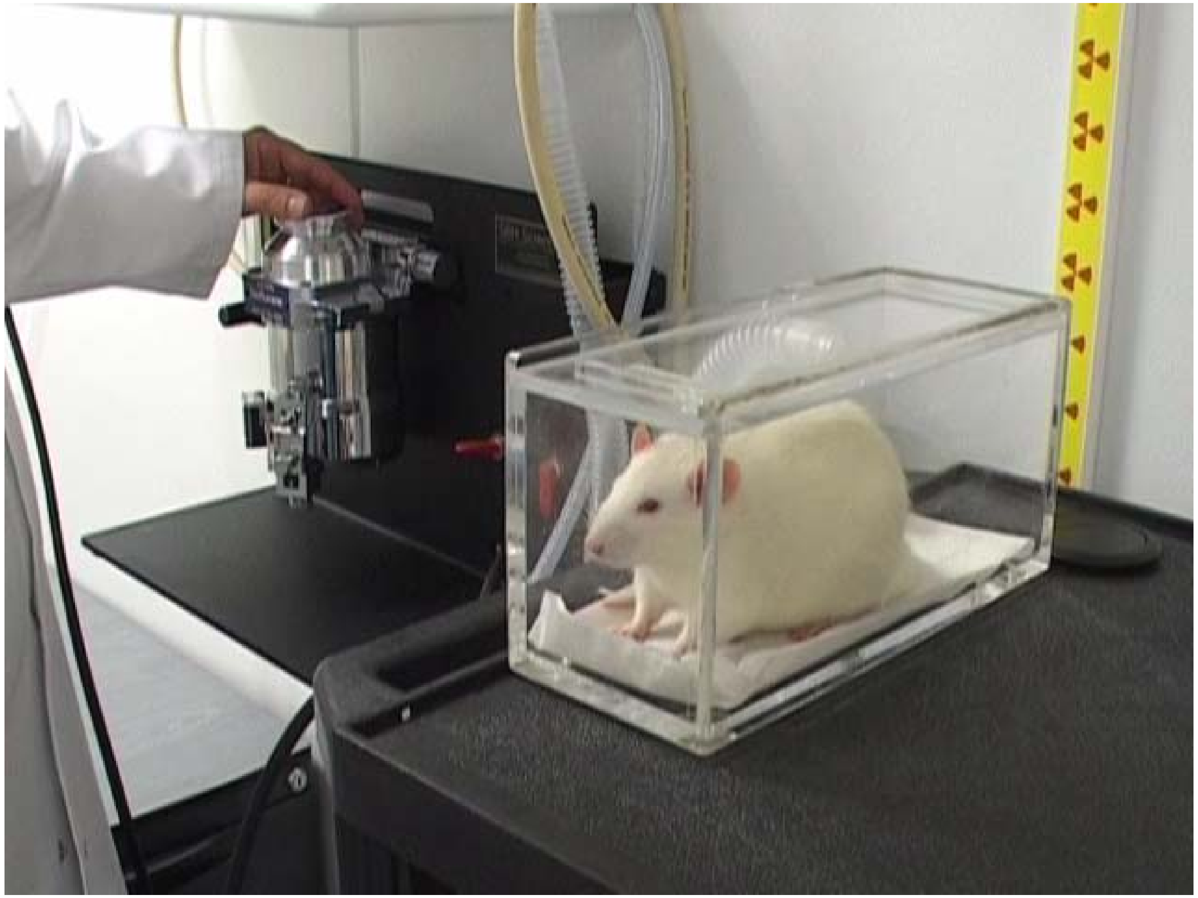
In vivo Micro scanner X

Automatic Synchronisation



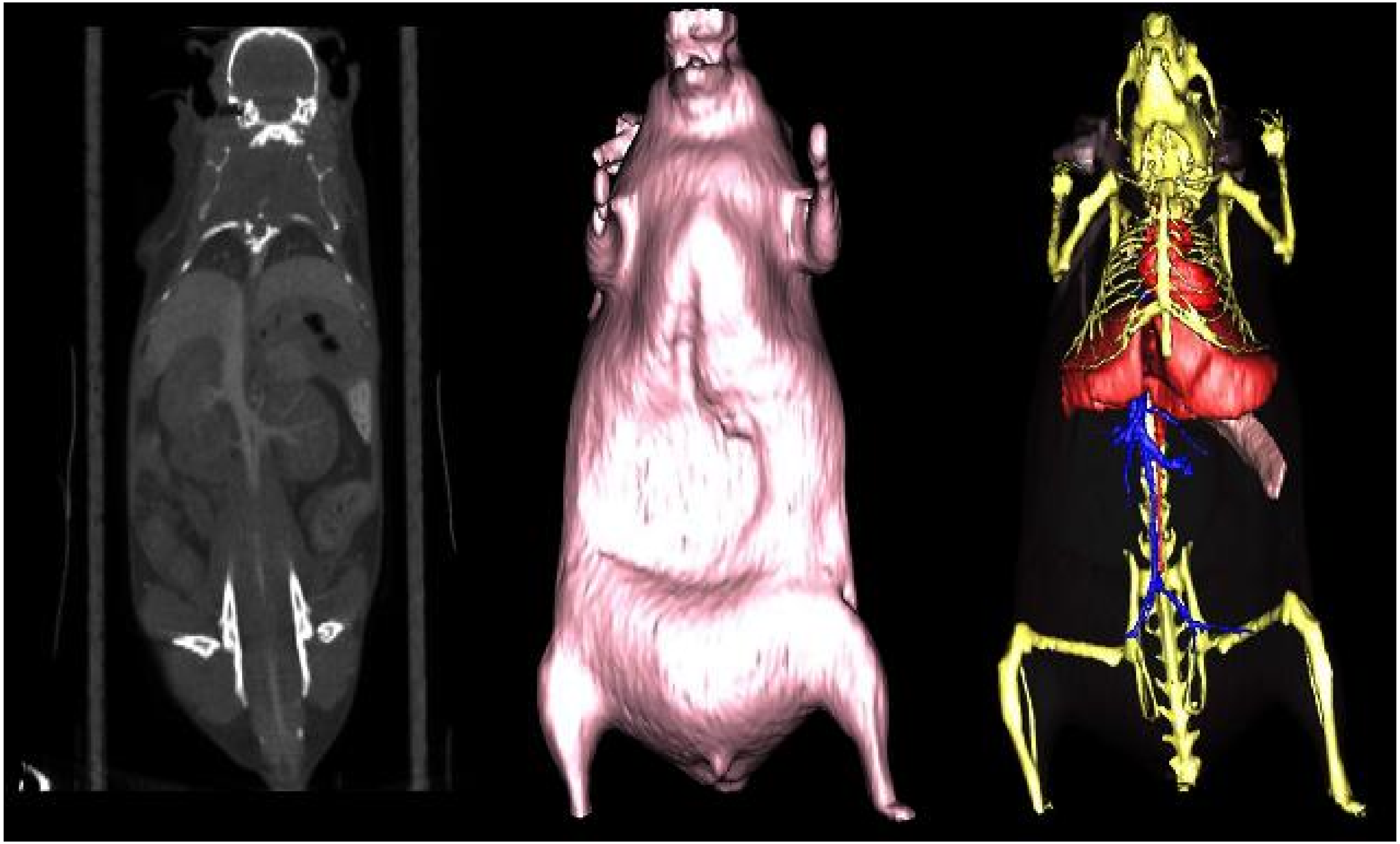
New tool for fundamental research

Air or Hexabrix or Telebrix : like human



Keep the animal alive !…

New tool for fundamental research



Intravenous Fenestra LC + Fenestra VC

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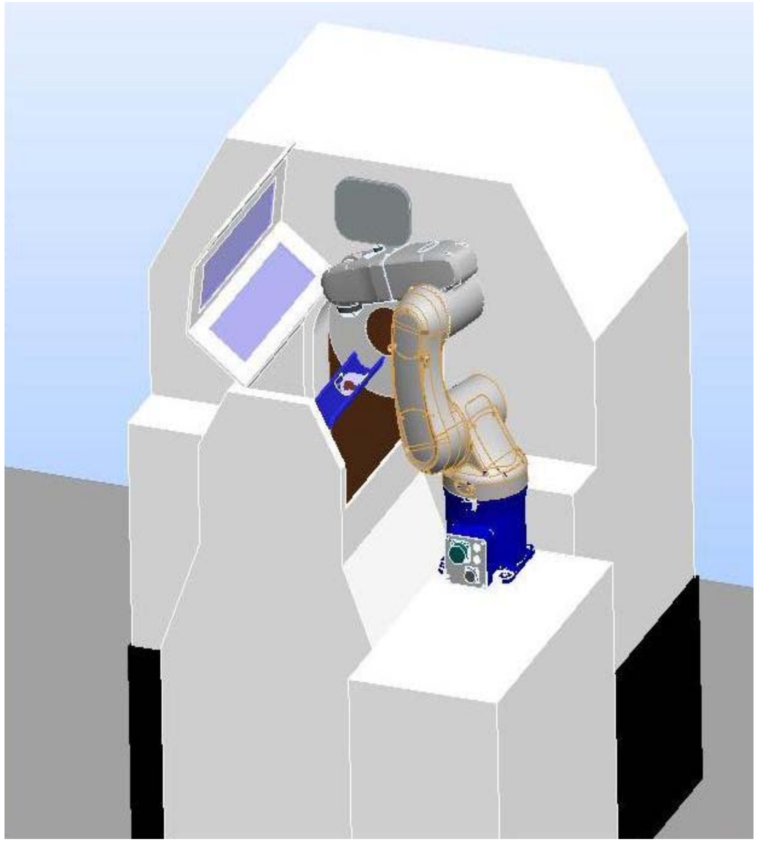
Robots for fundamental research

VisualSonic Vevo Product



IRCAD/LSIIT Project

Robotised injection

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Limits …

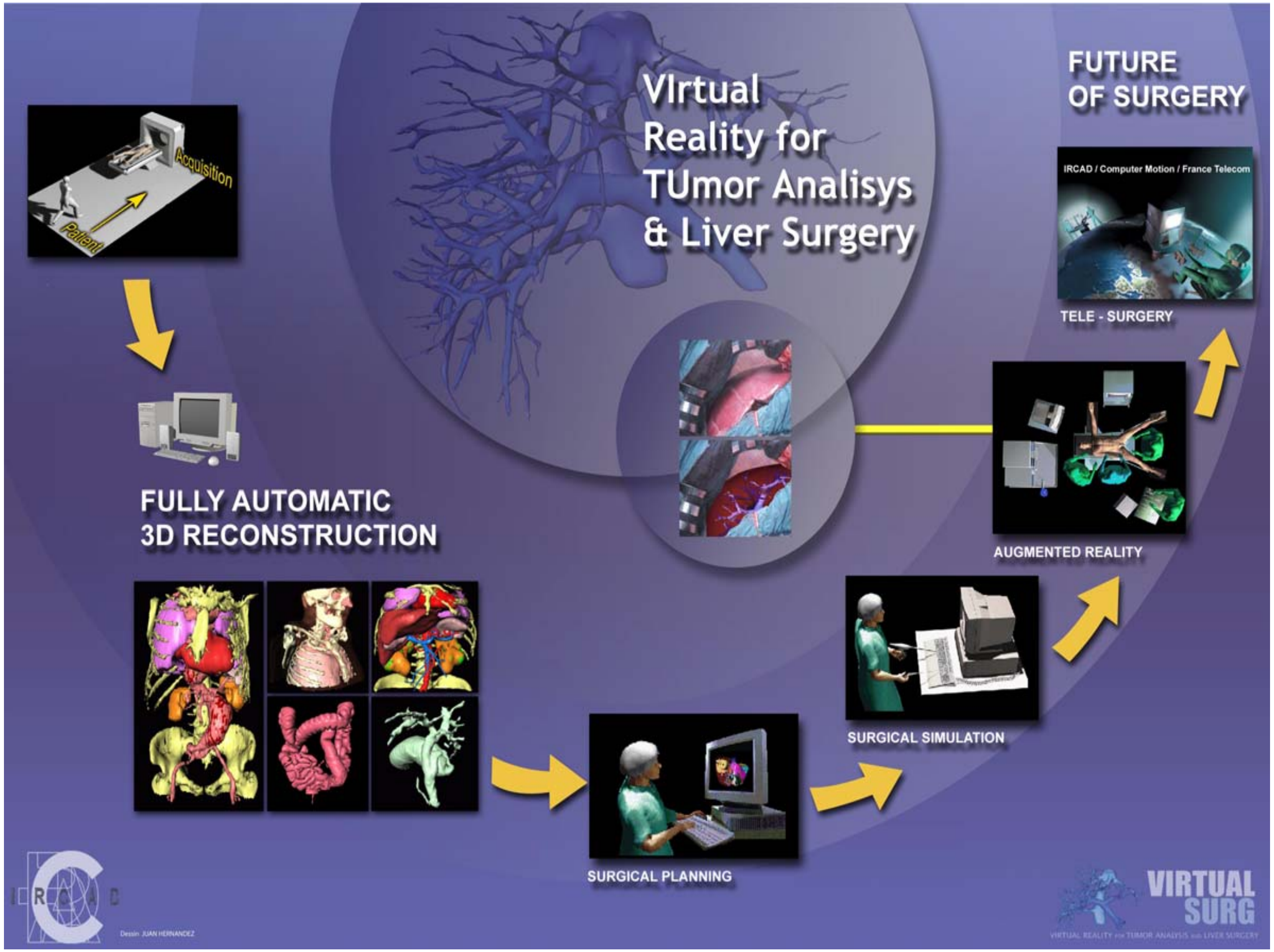
Is it the same automated segmentation than for human images ?

No : Image and anatomy are different

But : Usually good quality images with higher contrast than in human onto targeted organs.

Specific method can be easily developed

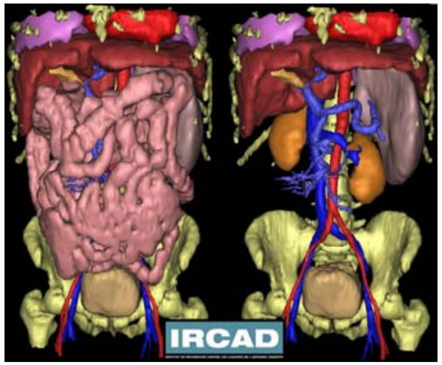
Surgical Planning

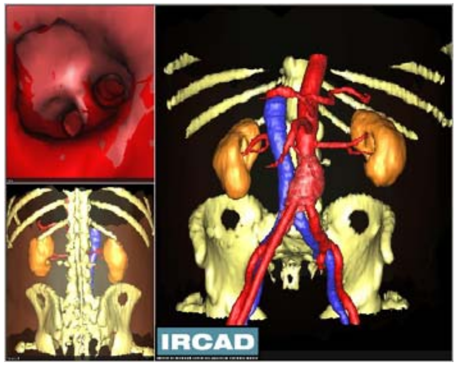


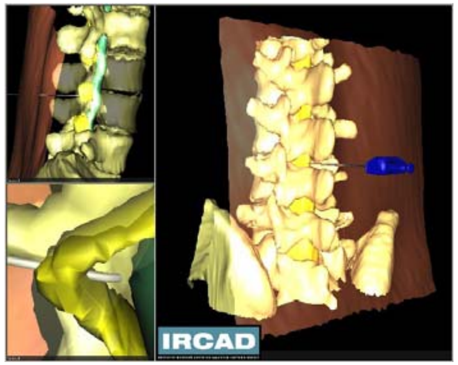
Second step : Surgical planning

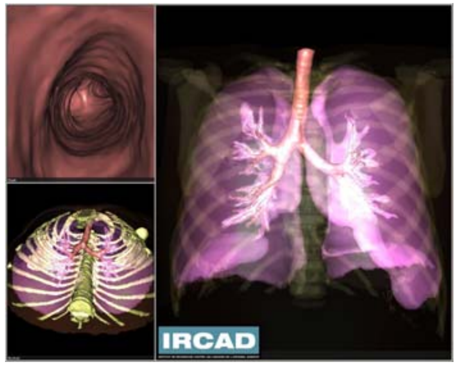
Dedicated Software

Working on a simple PC



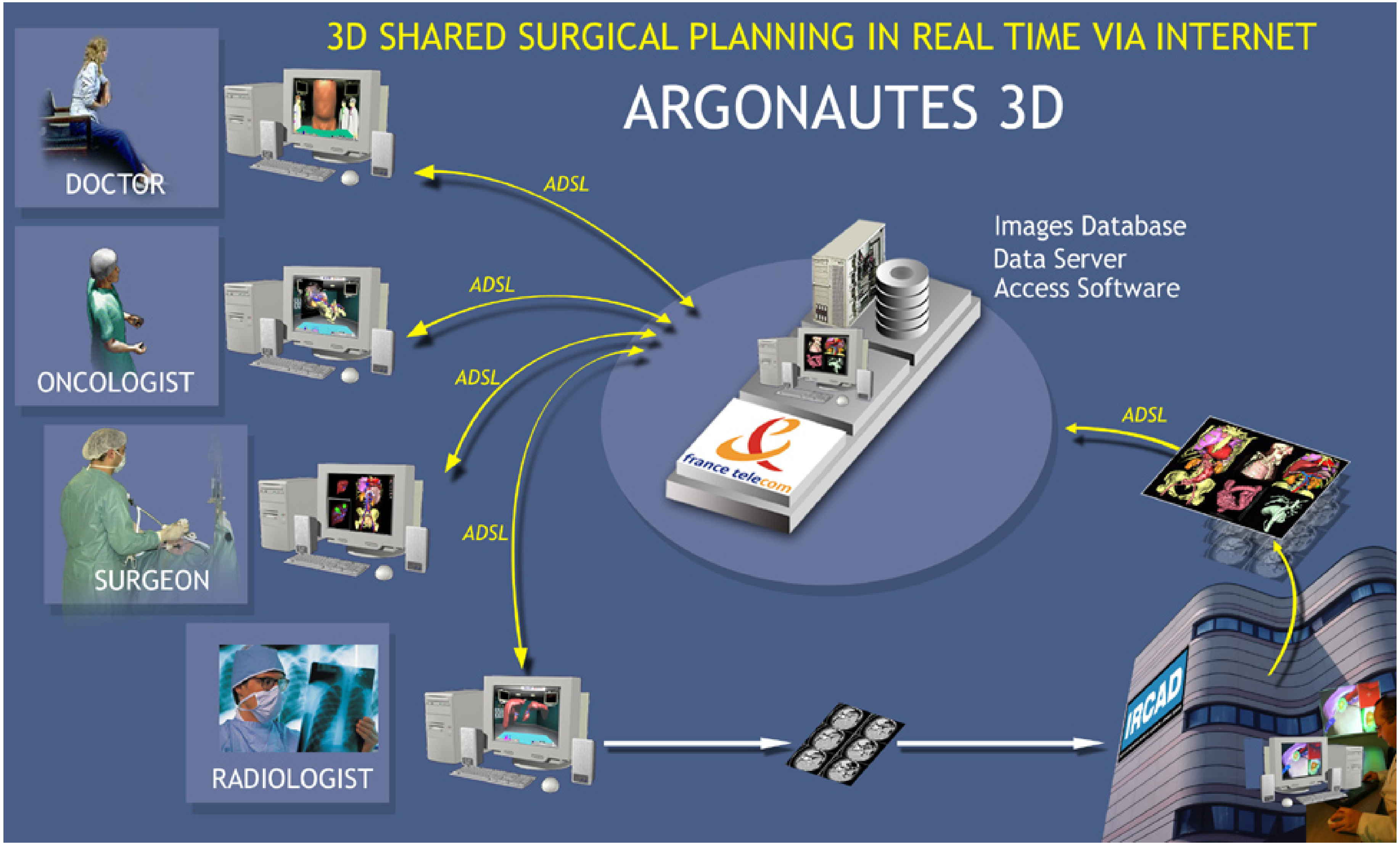






Live demonstration

Second step : Surgical planning



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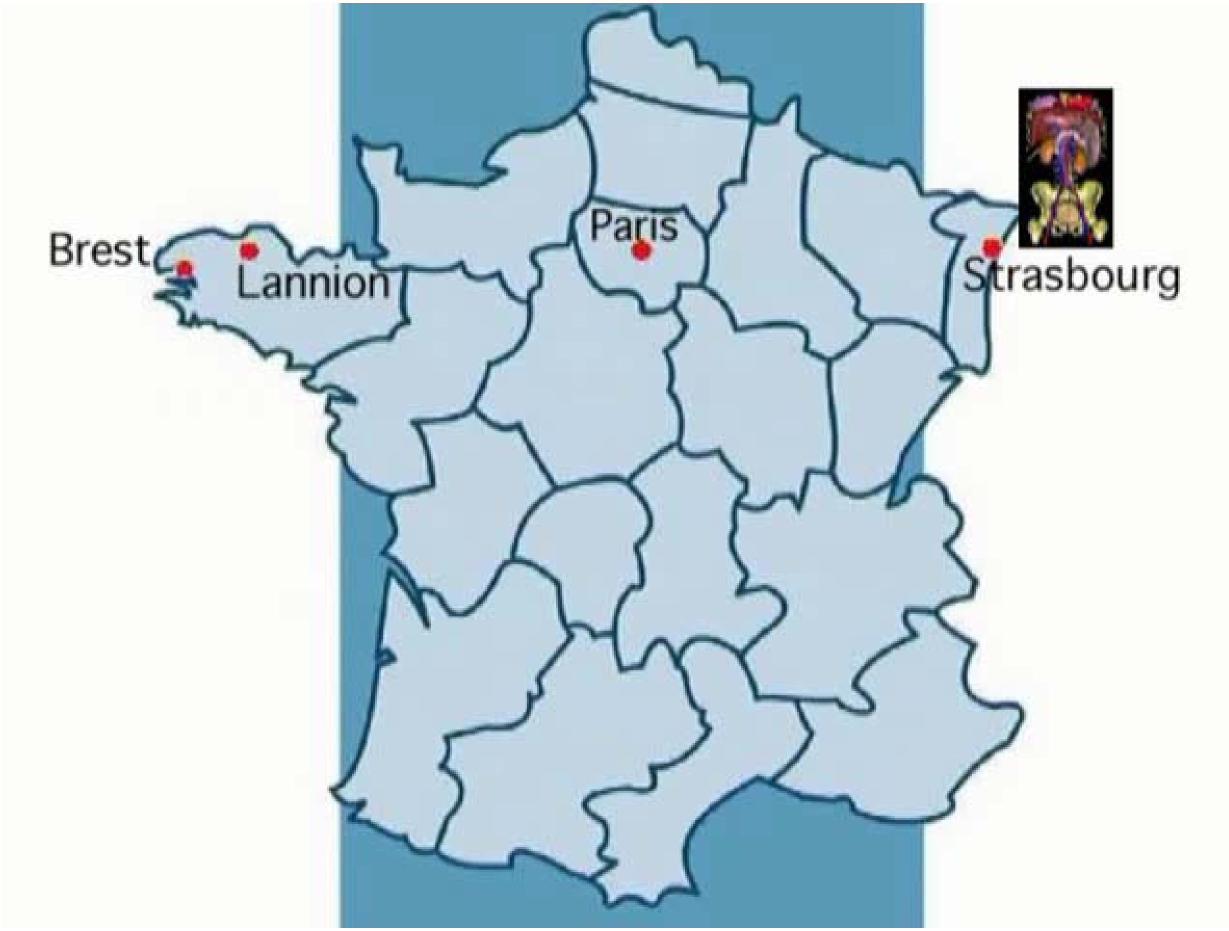
Second step : Surgical planning

5 novembre 2002 : ARGONAUTE 3D



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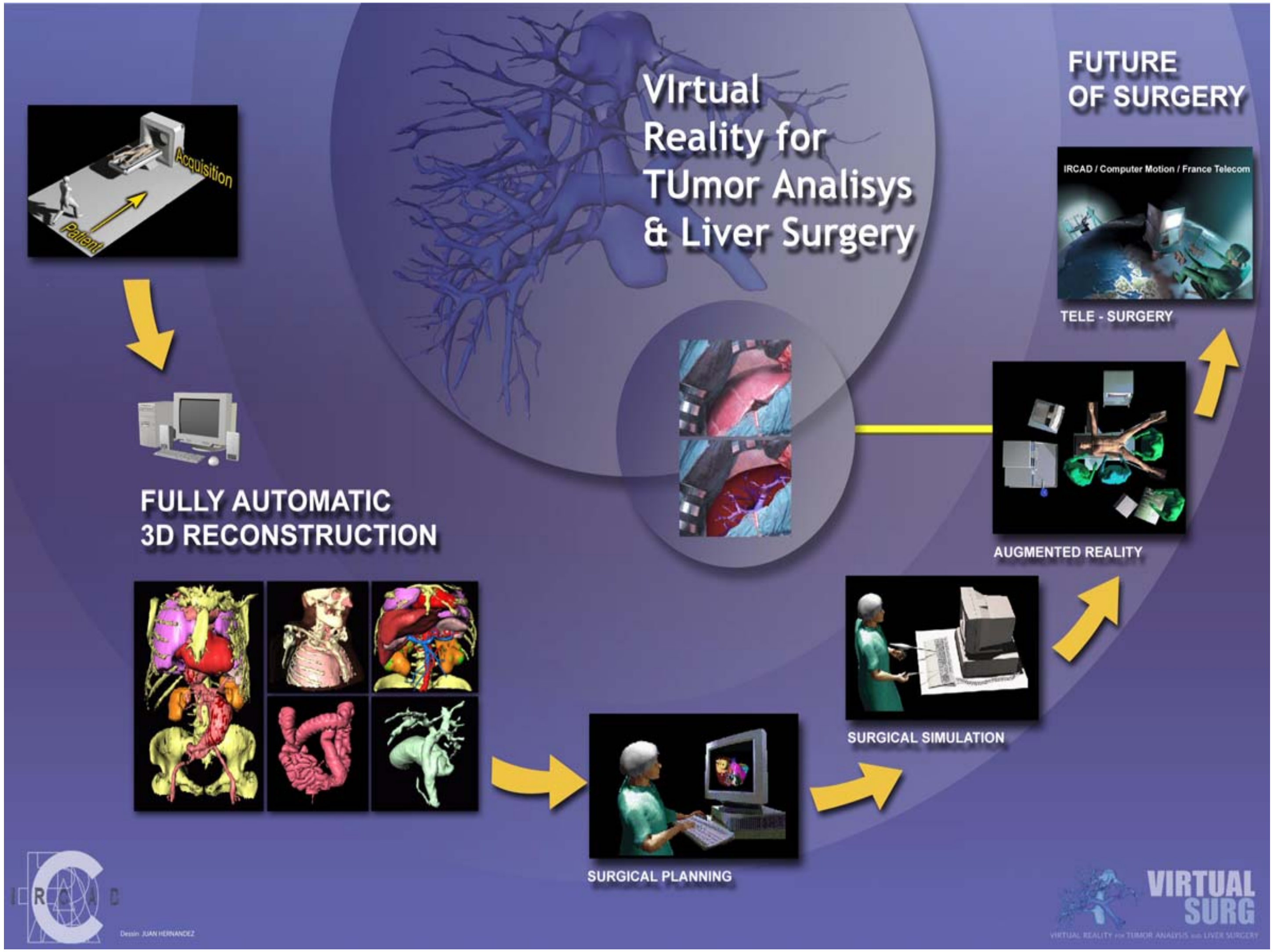
Limits …

Do we need more ?

Yes, but not a lot…

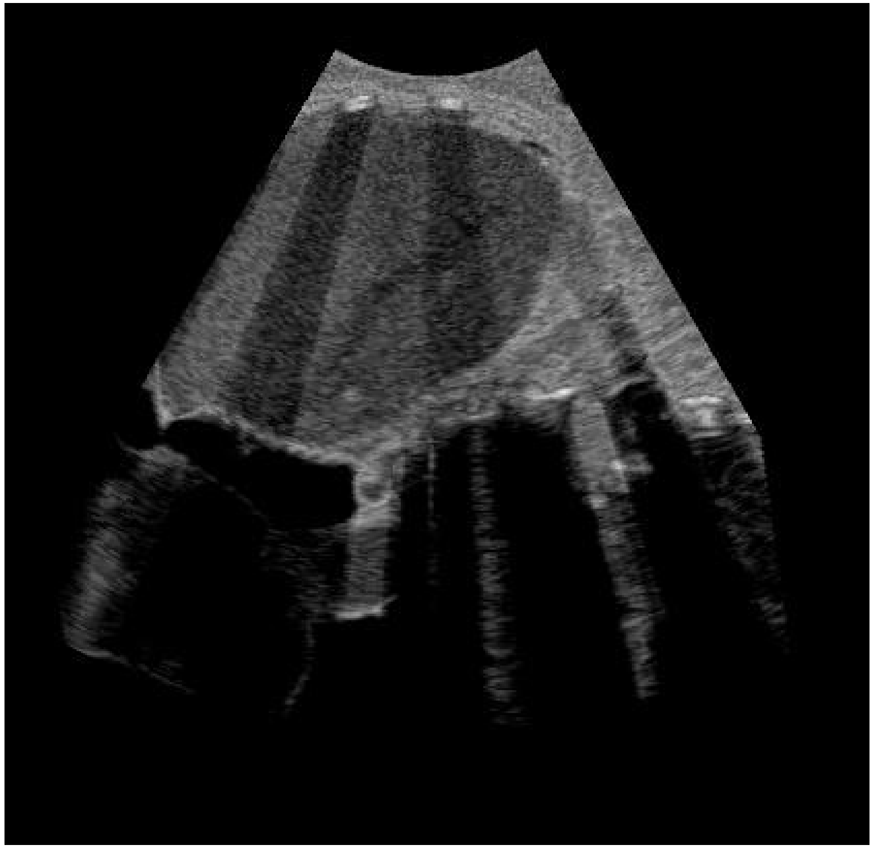
Software has to combine volumetric rendering and surface rendering, with the preservation of the laptop use.

Third Step : Surgical Simulation



Third Step : Surgical Simulation

Ultrasonographic Simulator



From CT-scan of the patient

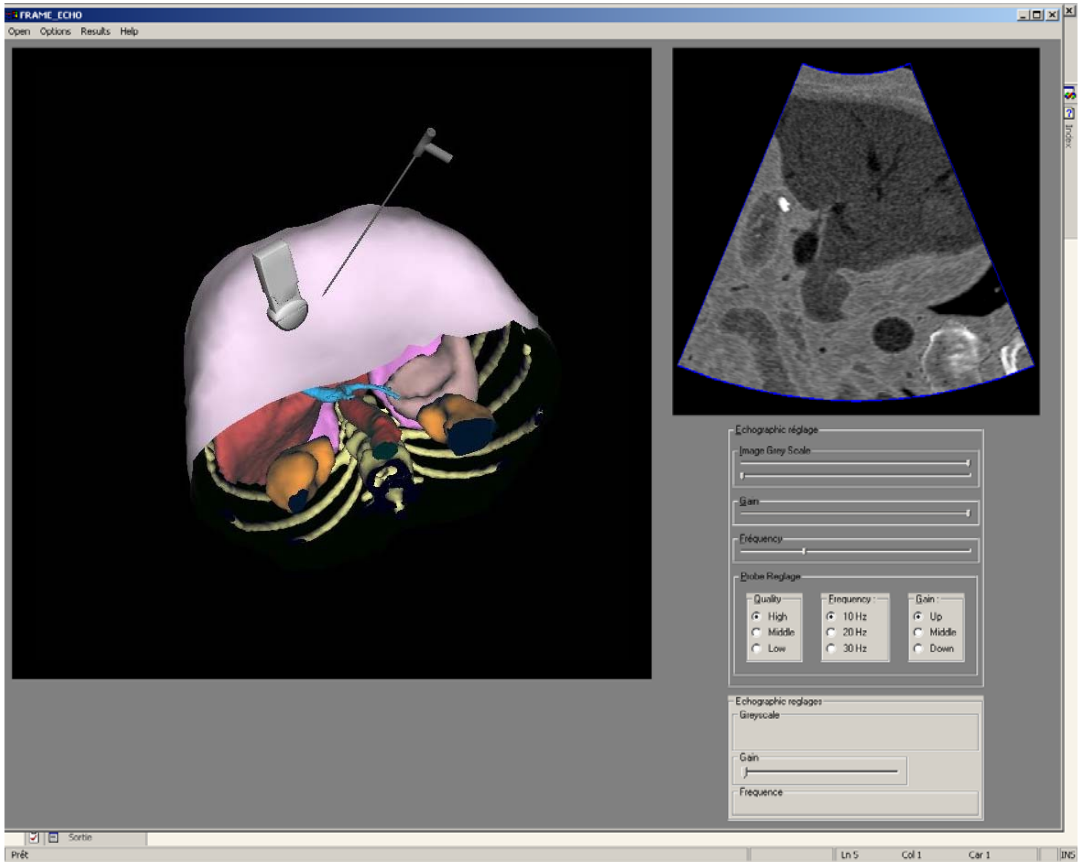
Third Step : Surgical Simulation

Fully Realistic Rendering

Where is the real ?

Third Step : Surgical Simulation

ultrasonographic percutaneous needle insertion Simulator



Third Step : Surgical Simulation

Ultrasonographic Simulator

From CT-scan of the patient

Third Step : Surgical Simulation

Real-time Force feed-back simulation

INRIA

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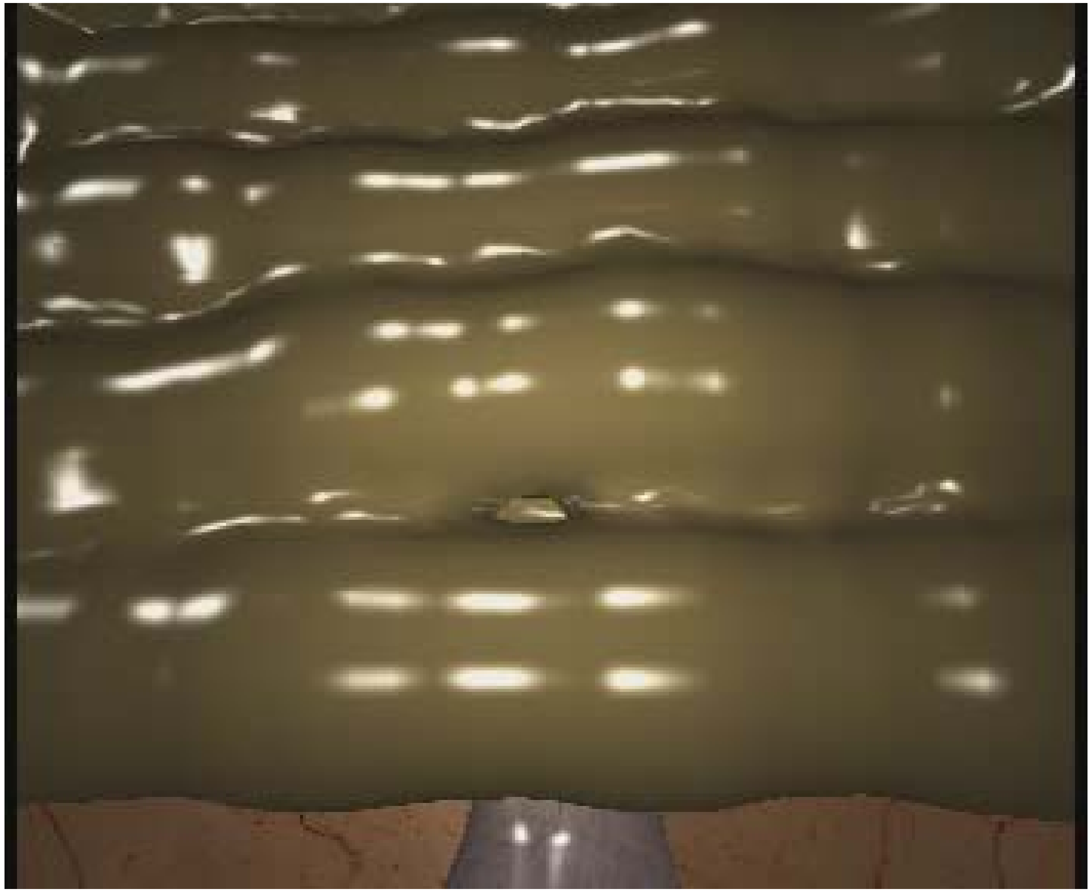
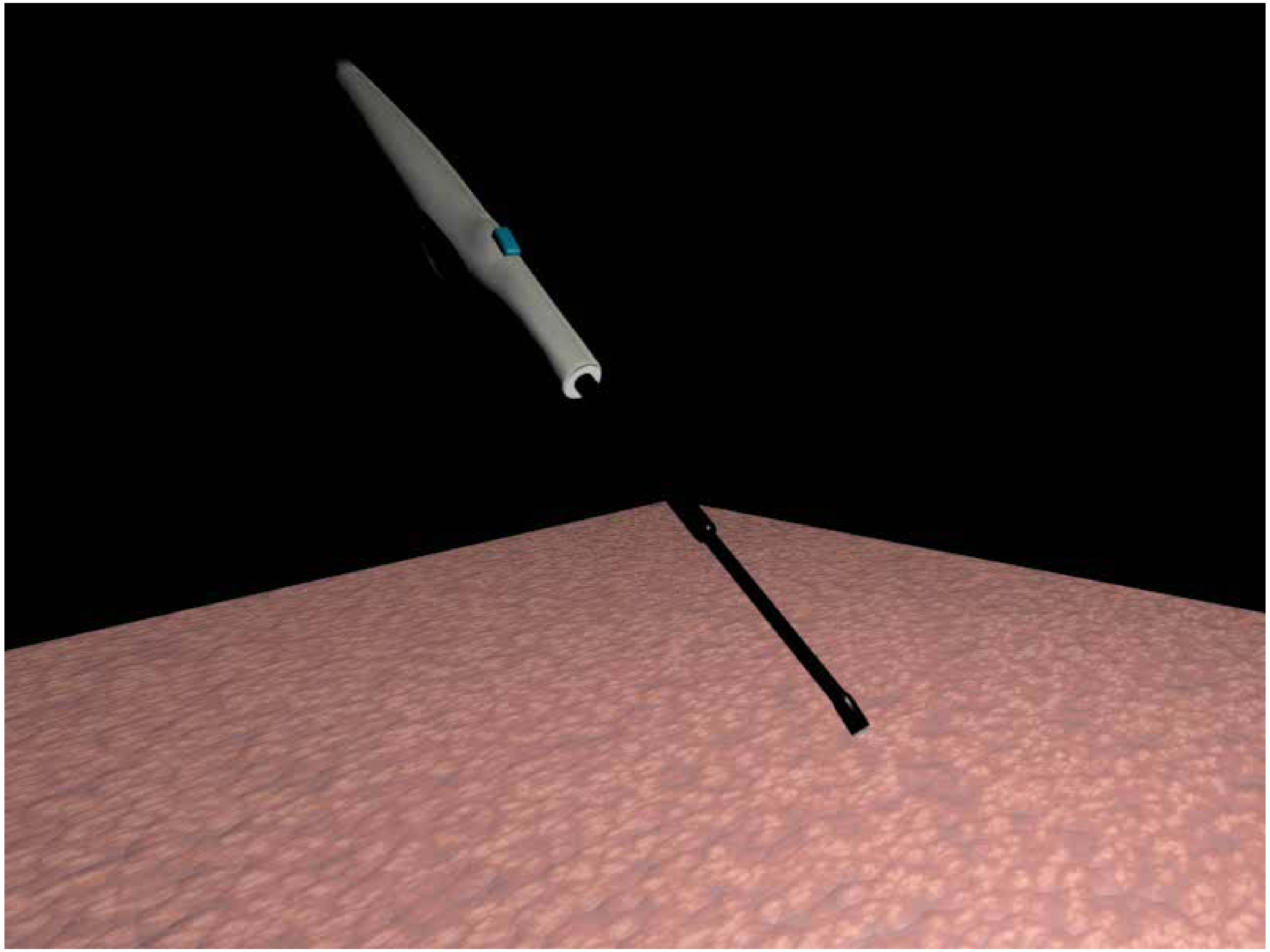
Third Step : Surgical Simulation

Real-time Force feed-back simulation



Surgical Simulation : ODYSSEUS

Next Step : more realistic visual effects



Limits …

Is Simulation enough realistic for education and training?

Yes and No.

Real Precision limit due to :

- The loss of a lot anatomical structures non visible onto medical images,
- Limited fluid simulation
- Forces estimation and not the real patient values

Limits …

Is Simulation not too expensive for education and training ?

Yes and No.

Force feedback not always expensive

The Cost is not a real problem for pre-operative use

Force feedback not always needed (robotic)

Force feed-back devices

Name of System / Nb DOF	Omni / 3 DOF	Phantom Desktop / 3 DOF	Phantom 1.5 / 6 DOF
Workspace : W x H x D	16 x 12 x 7 cm	16 x 12 x 12 cm	19.5 x 27 x 37.5 cm
Position resolution	> 450 dpi., ~0.055 mm	1100 dpi , 0.02 mm	860 dpi , 0.03 mm
Maximum exertable force	3.3 N	7.9 N	8.5 N
Continuous exercable force	> 0.88 N	1.7 N	1.4 N
Stiffness	~ 1.5 N / mm	3.16 N/mm	3.5 N/mm
Apparent mass at tip	<45 g	<45 g	<75 g
Computer interface	IEEE-1394 FireWire	IEEE-1394 FireWire	IEEE-1394 FireWire
Cost	~1.300 € HT	~13.000 € HT	~43.000 € HT

Force feed-back devices

force dimension

Name of System with Nb DOF	3 DOF Omega	3 DOF Delta	6 DOF Delta
Workspace : W x H x D	16 x 16 x 12 cm	36 x 36 x 30 cm	36 x 30 x 37.5 cm
Position resolution	0.009 mm	0.02 mm	0.03 mm
Maximum exertable force	12 N	20 N	20 N
Continuous exercable force	12 N	20 N	20 N
Stiffness	14.5 N / mm	15 N/mm	15 N/mm
Apparent mass at tip	0 g : full gravity compensation	0 g : full gravity compensation	0 g : full gravity compensation
Computer Interface	USB 2.0 , PCI I/O	PCI I/O	PCI I/O
Cost	~13.000 € HT	~21.000 € HT	~38.000 € HT

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Other devices for simulation

Name of System, Nb DOF	Virtual Laparoscopic Interface / 5 DOF	Laparoscopic Surgical Workstation / 5DOF
Pitch x Yaw x Insertion	140° x 90° x 20 cm	100° x 100° x 17 cm
Position resolution	0.064° / 0.056 mm	0.01° / 0.008 mm
Rotation	540°	180°
Max/Continuous Pitch & Yaw	No force feed-back	0.85 Nm / 0.47Nm
Max / Continuous Force	No force feed-back	19 N / 11 N
PC connection	RS 232 Serial	PCI interface card
Cost	~6.800 € HT	~34.000 € HT

Other devices for simulation

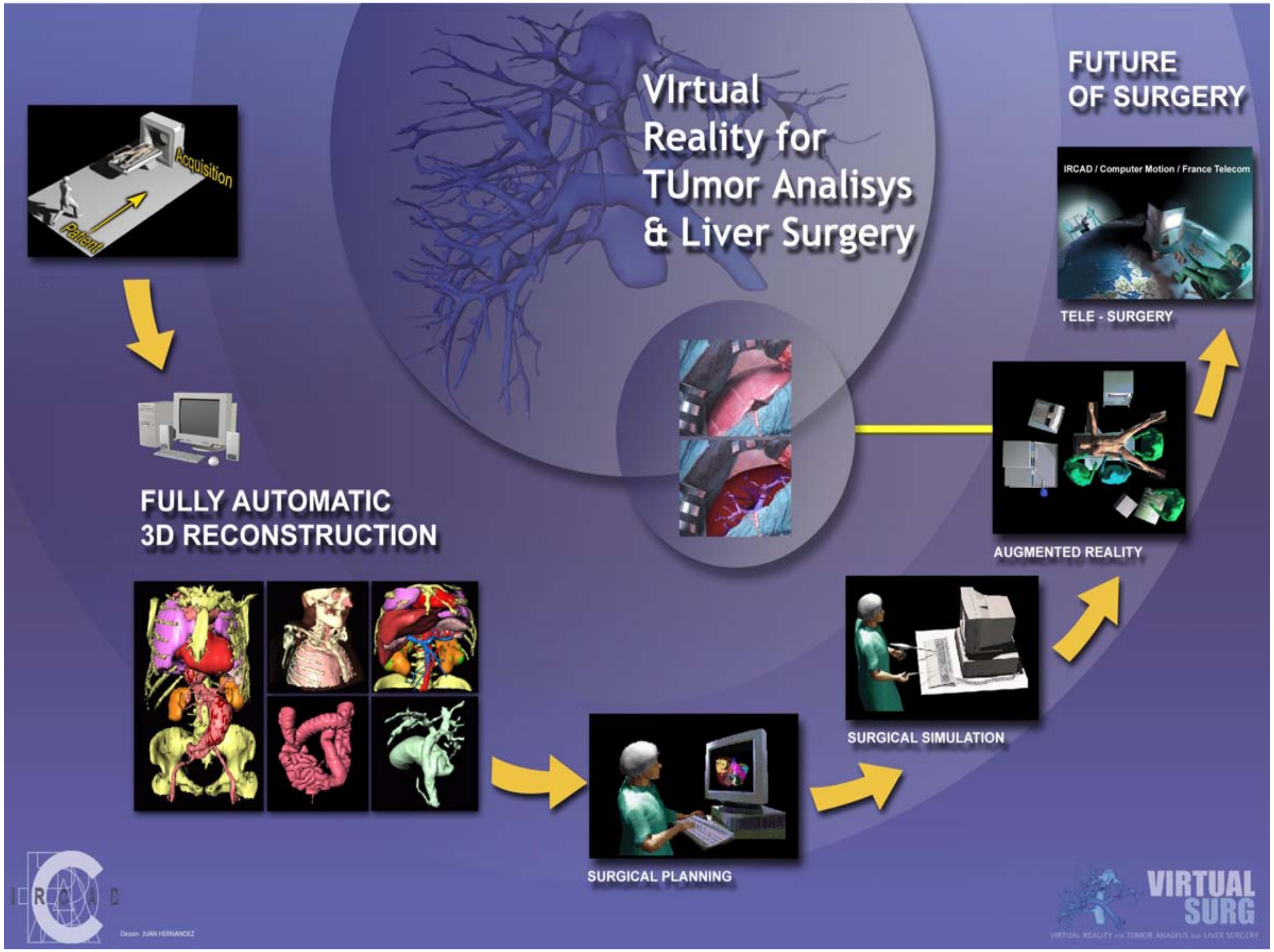
1 DOF FFB for endoscopy and catheter insertion

New devices : low cost

No FFB / 5DOF
Simendo
~300 €

3 DOF FFB
Novint Falcon
100 $

Intra-operative Use



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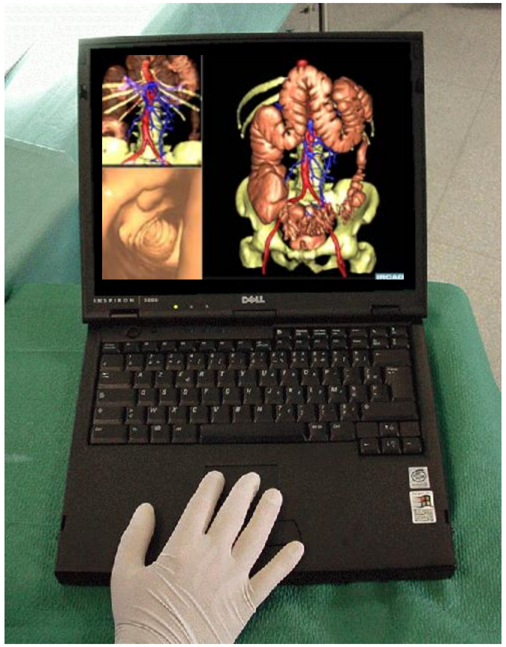
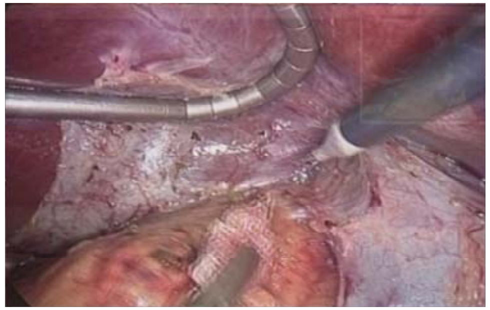
Surgical planning software

Open or laparoscopic Surgery

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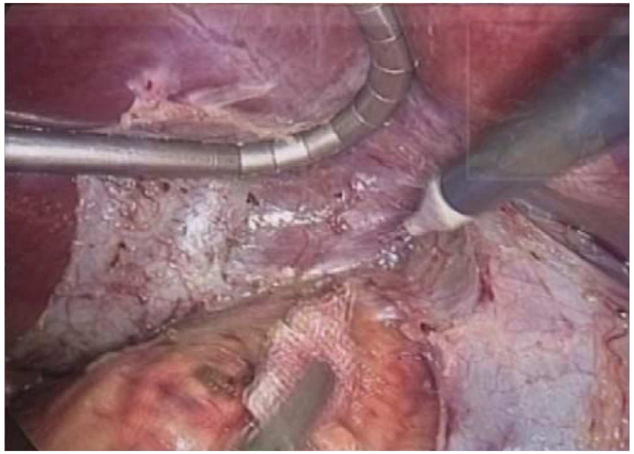
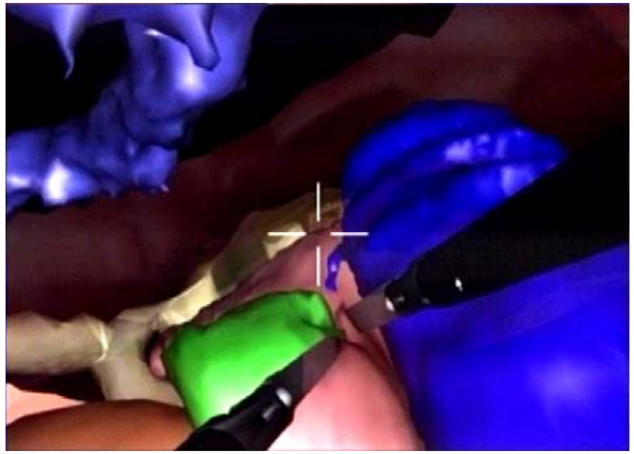
Forth Step : Intra-operative Use

Surgical views

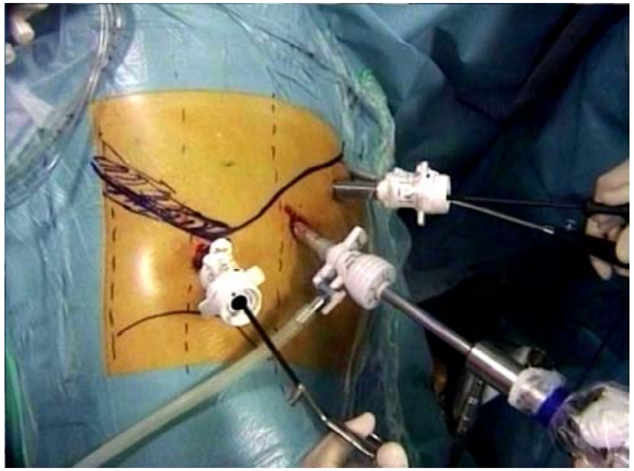
Laptop views

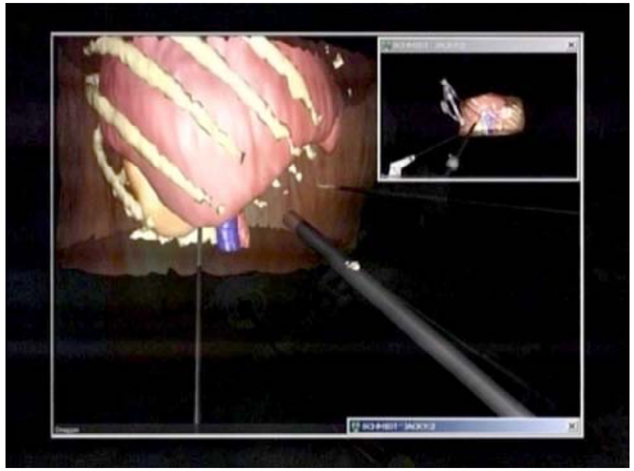




Internal view

Real Virtual





External view

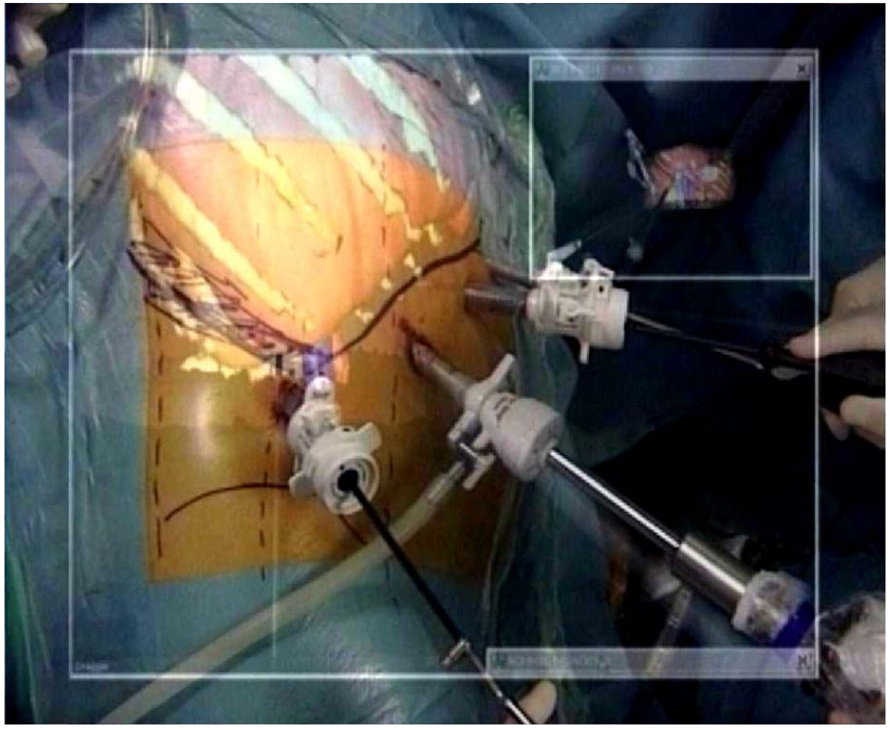
Real Virtual

Forth Step : Intra-operative Use

Optimal use : Fuse real and virtual

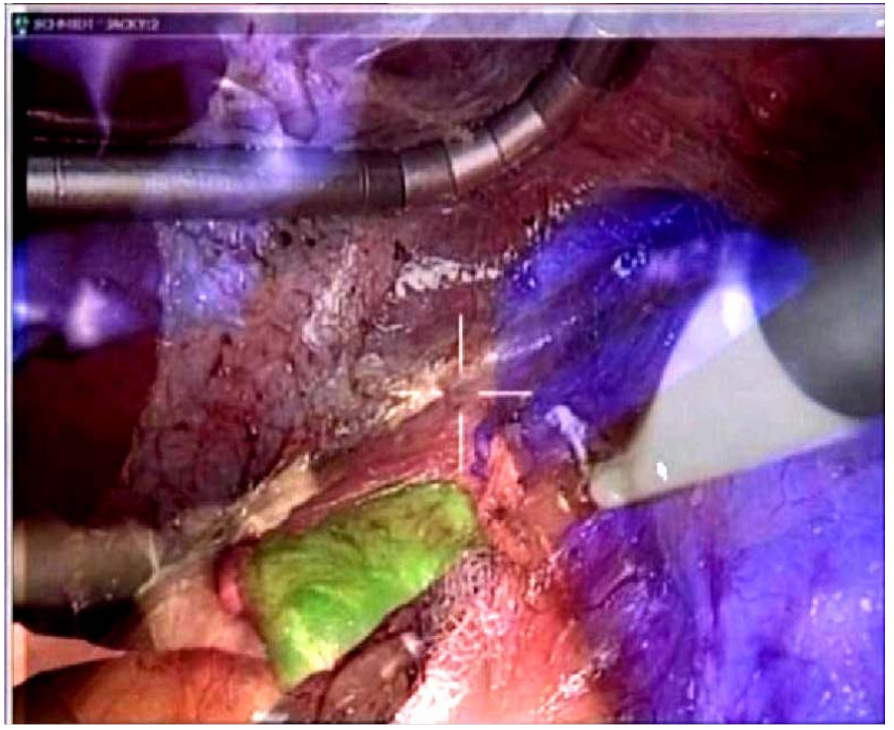
External view

Real + Virtual

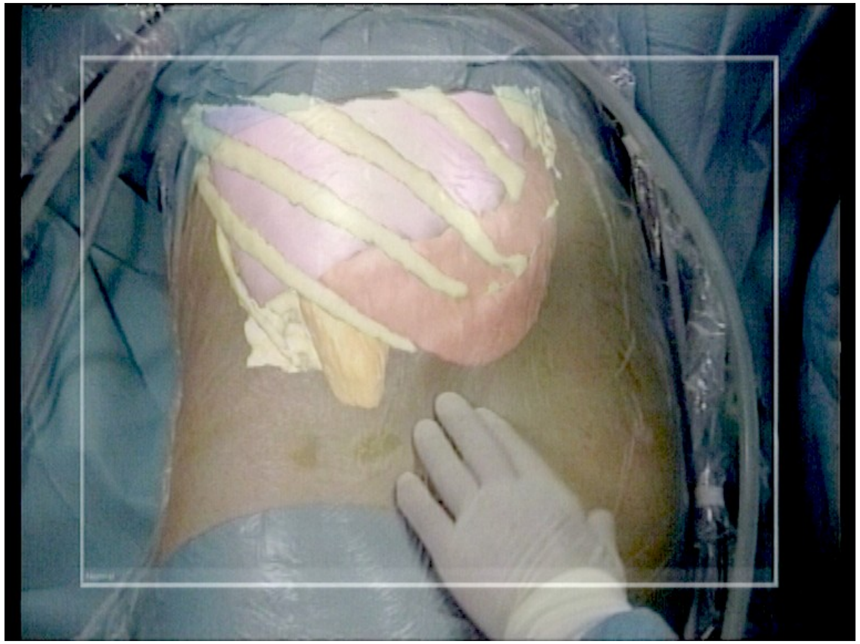


Internal view

Real + Virtual

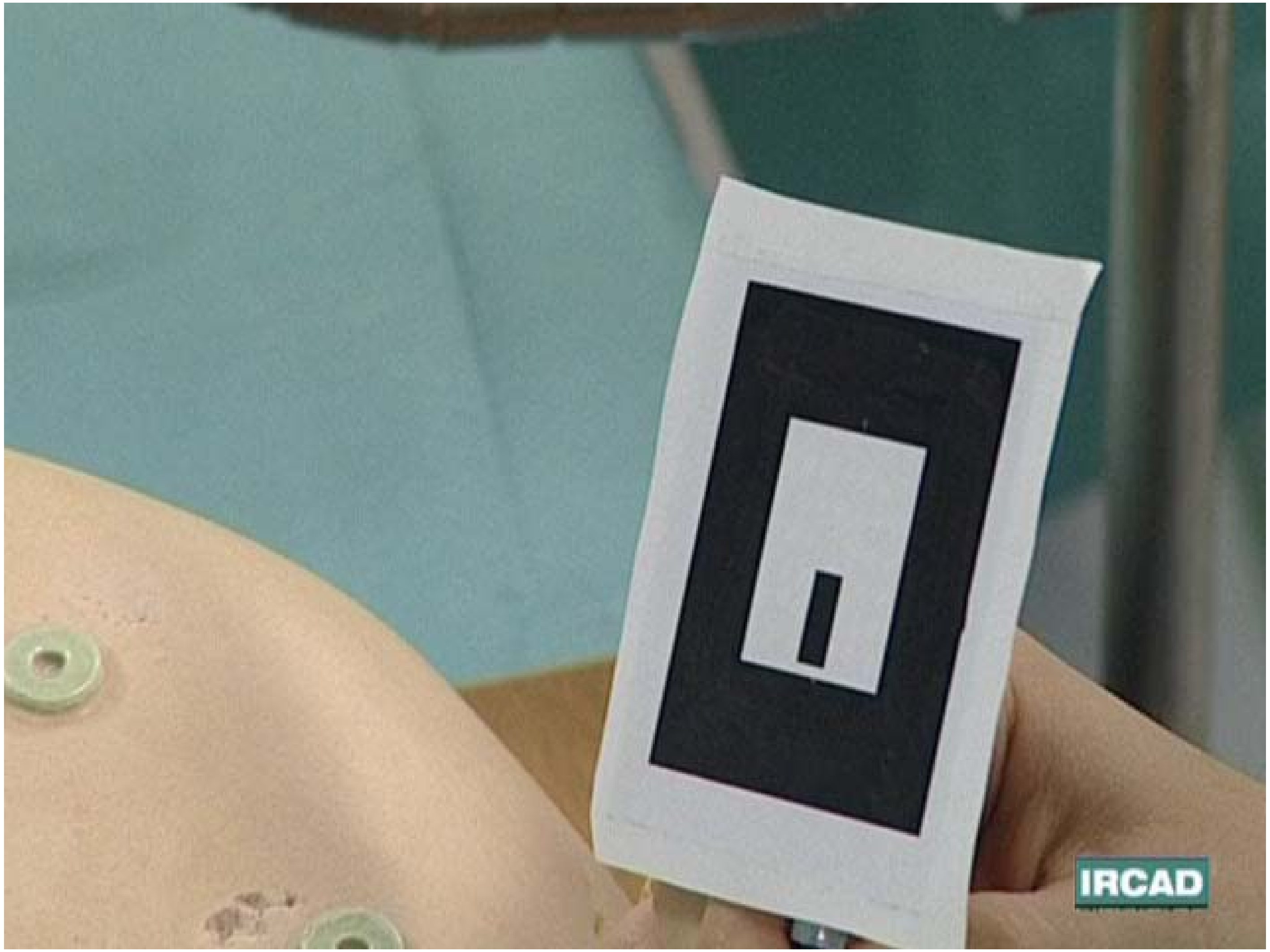


Interactive Augmented reality



JAMA November 2004

Fully Automated Augmented reality



Limits …

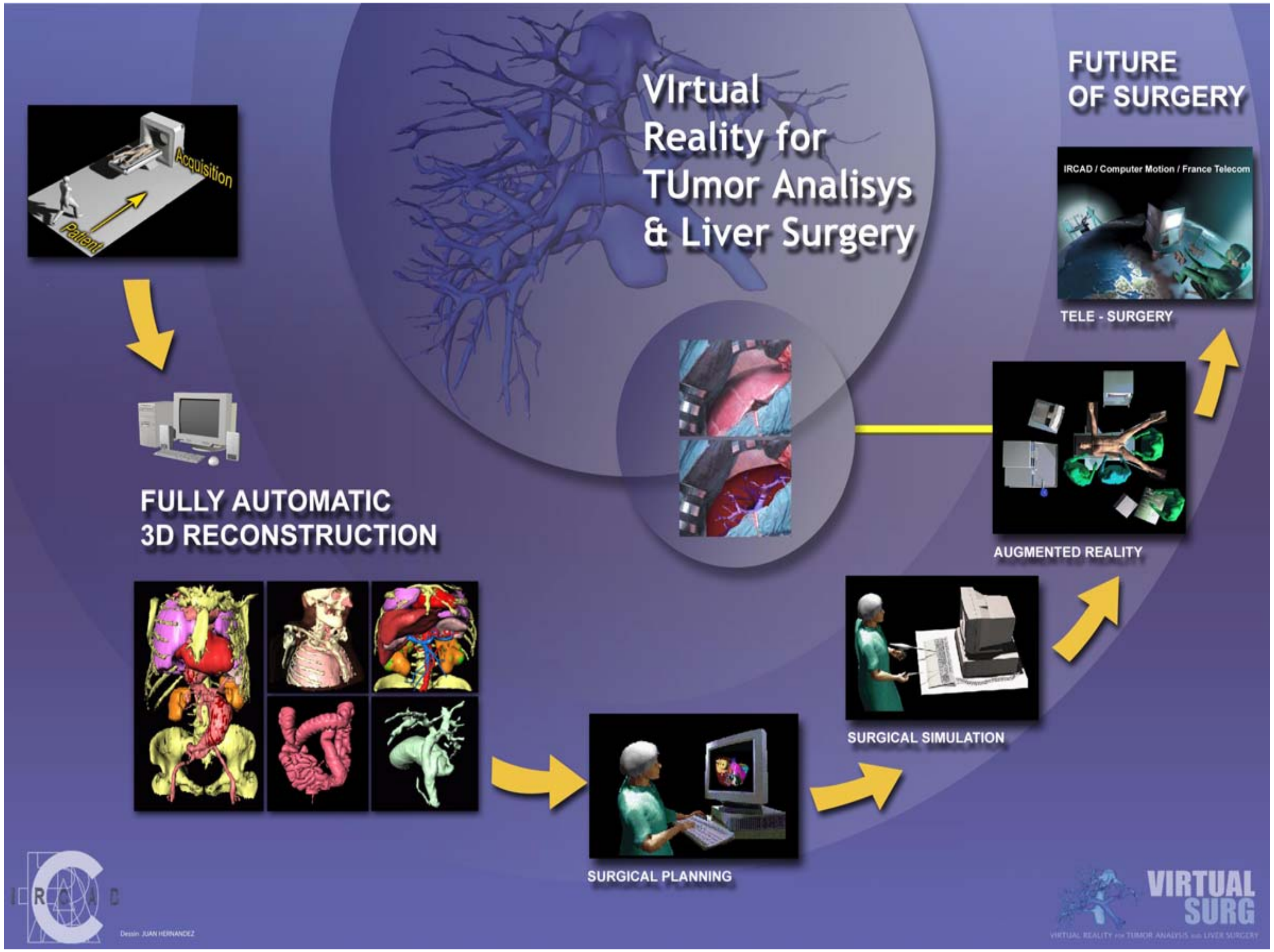
What about breath or patient movement ?

Today not yet a solution for a real-time registration of deformable model in movement

But : intermediary solutions are possible for limited movements

Per-operative imaging is better and could replace the real-time registration problem in a real time segmentation problem…

Robotics



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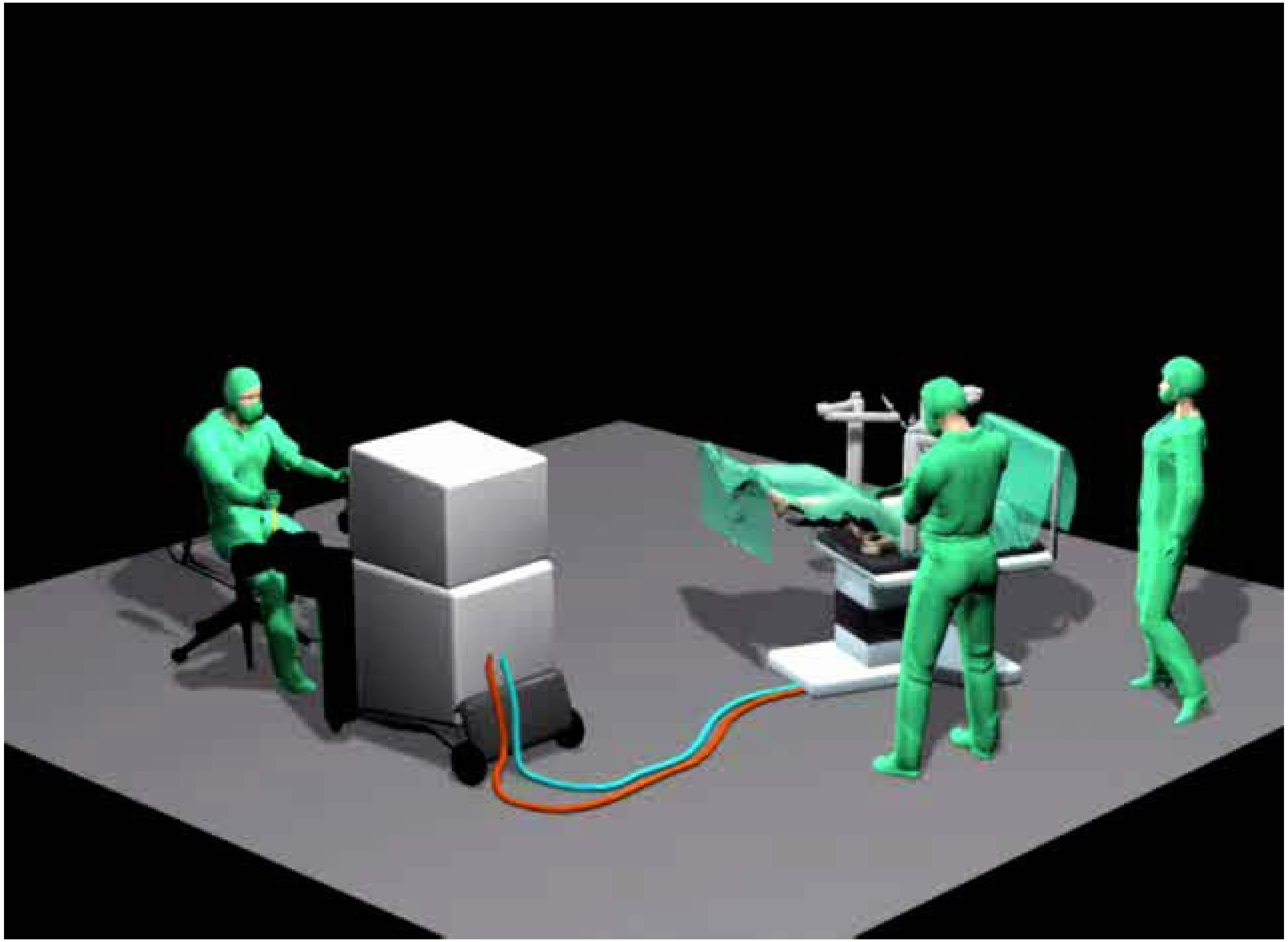
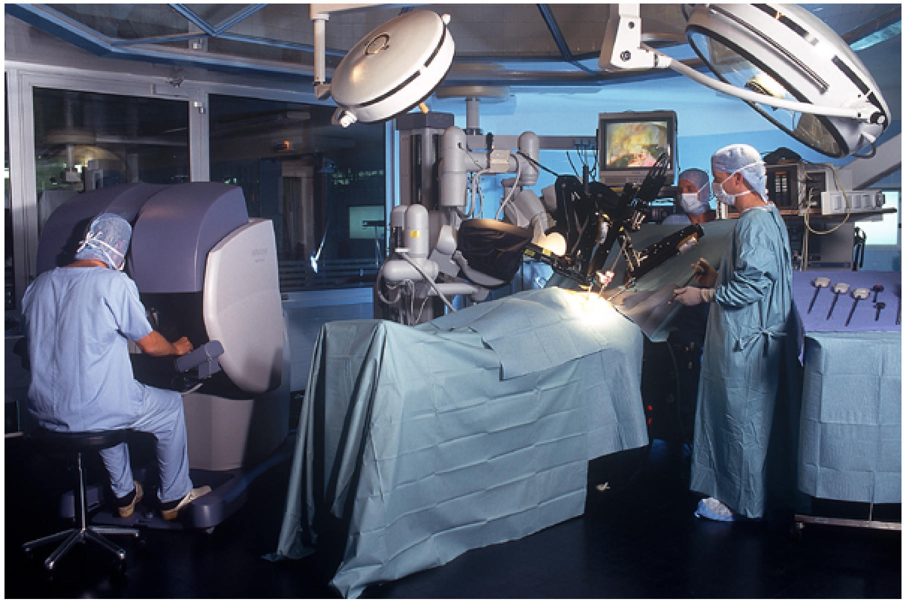
Robot : TeleSurgery



Robot : TeleSurgery

2 Robots, 1 Society : Intuitive Surgical

Da vinci



Zeus

But new solution are arising :
Artemis, Hitashi, Sinters, …

Robotics

Benefits

- Ergonomy
- Voice-controlled camera holder (ZEUS)
- 3D visualisation
- Dexterity (ambidextrous)
- Precision (.tremor-filtring .scaling)
- Range of motion (6° of freedom)

Limits

- No force feedback
- No automatic-tool changer
- Few energy-directed instruments
- Cost
- Ethical issue
- No scientific approach

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Robotics

State of the art

- Feasability but benefit ?

  General Surgery

- Enhancement of complex advanced procedures
  - *Internal mammary harvesting for coronary by pass grafting*
  - *Radical prostatectomy*
  - *Tubal anastomosis*

Limits …

What is the clinical value of this robots ?

No real rentability for surgery

But : Robotic must be use only for surgical gesture non possible without robot.

But : We need to add automated control in order to perform gesture impossible in routine

Robotics : An information system

Go further : Huge distance surgery

Robotics : An information system

Lindbergh Surgery : September the 7th 2001

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A medical revolution ?…

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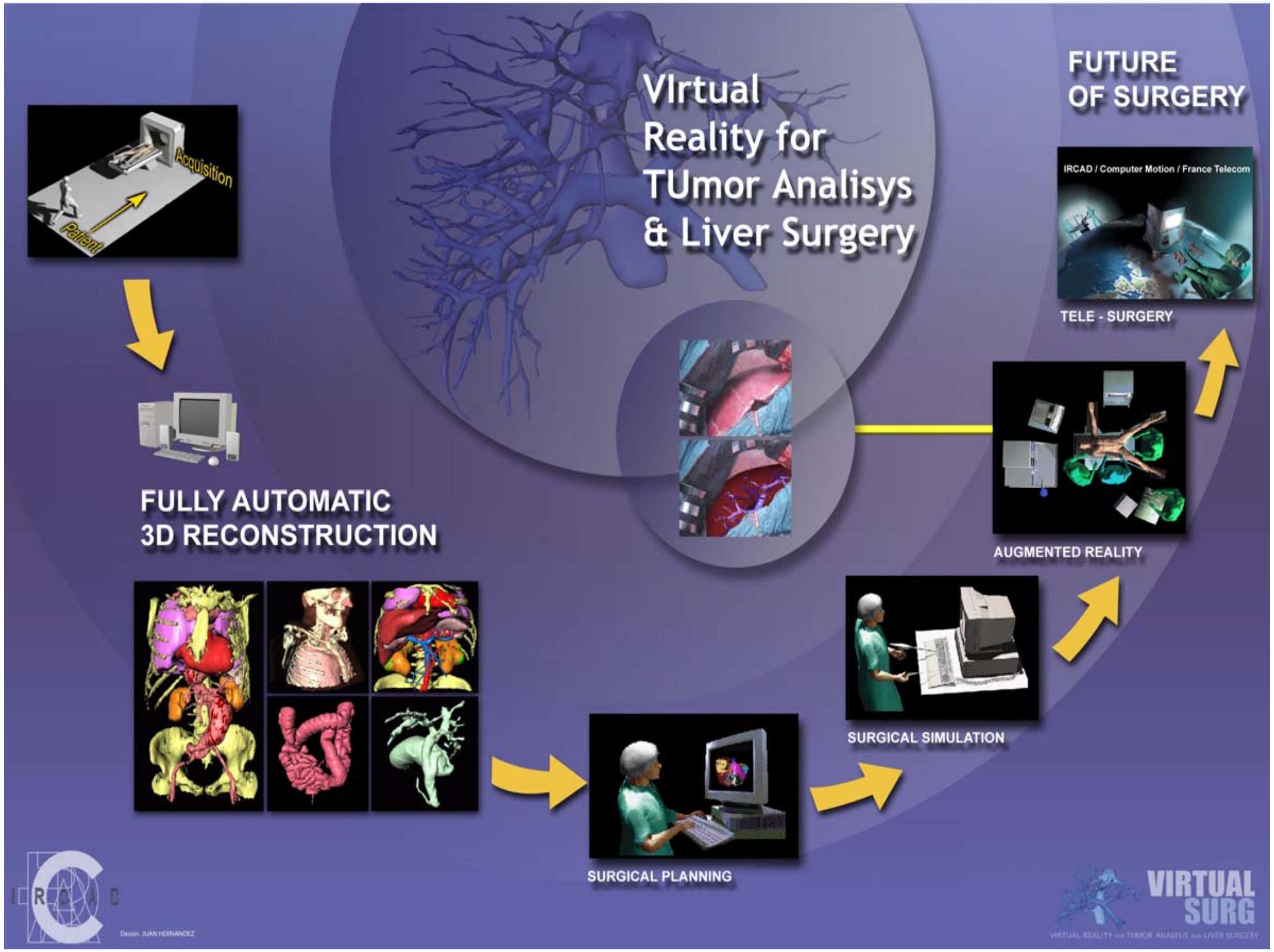
Robotic Tele-mentoring

*Courtesy of **InTouch Health***

Robotic Tele-mentoring

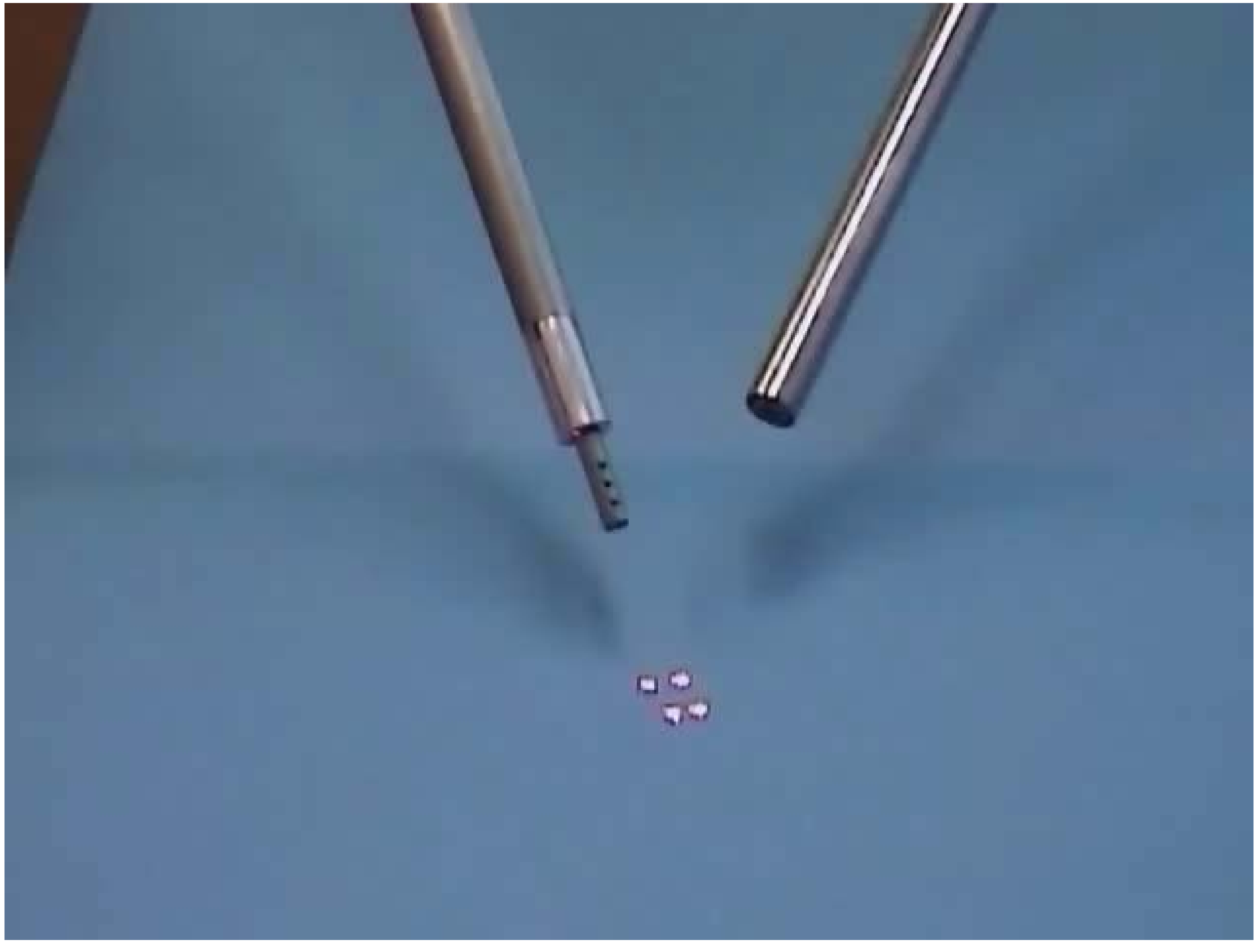
Tele-mentoring from Pocket PC

Robotics Automation



Visual servoing of Robotics

Visual Control

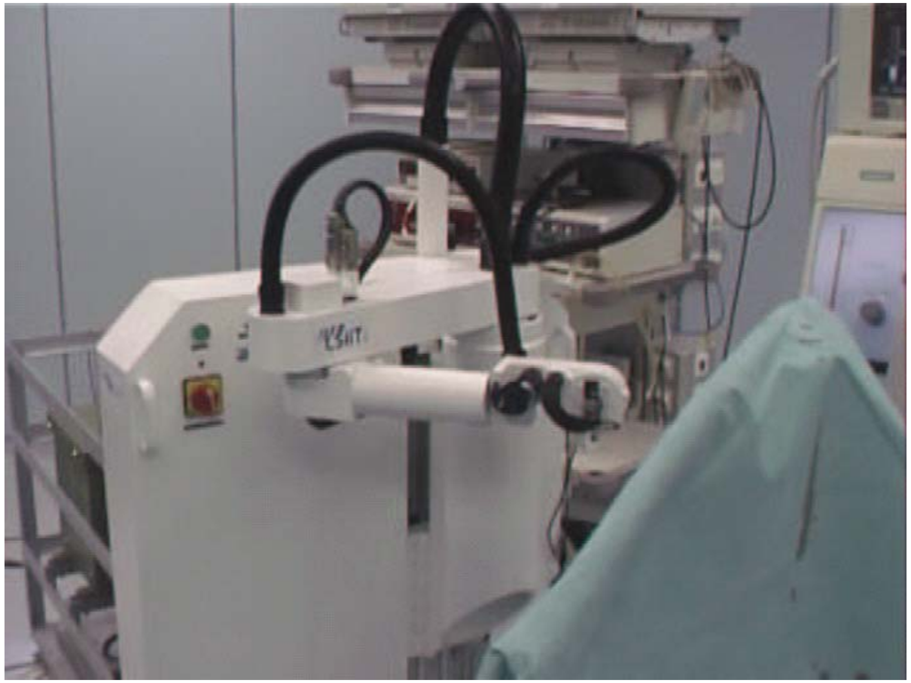


Visual servoing of Robotics

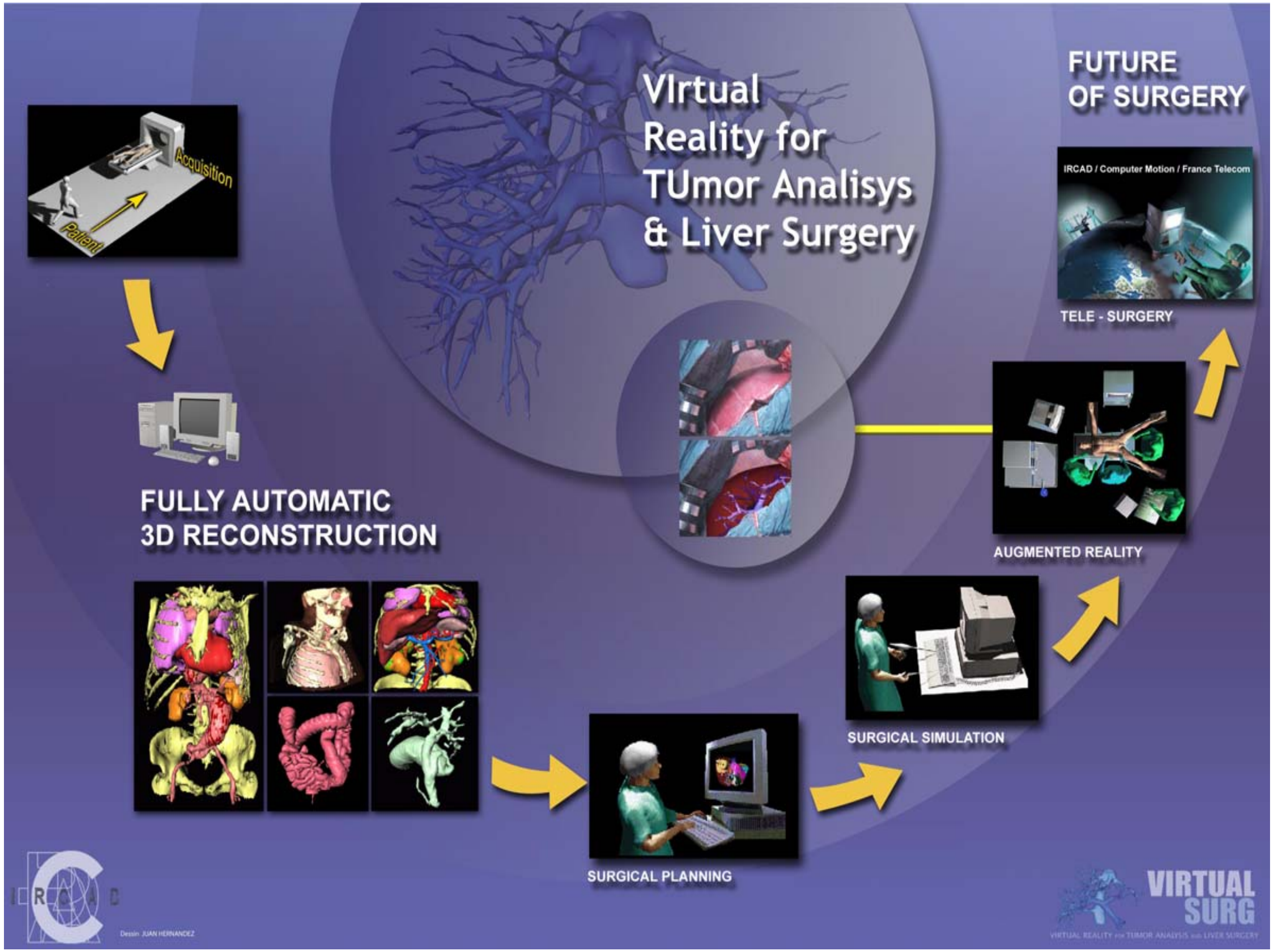
Visual Control

Visual servoing of Robotics

Visual Control



Future of Robotics



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Robotic Tele-mentoring

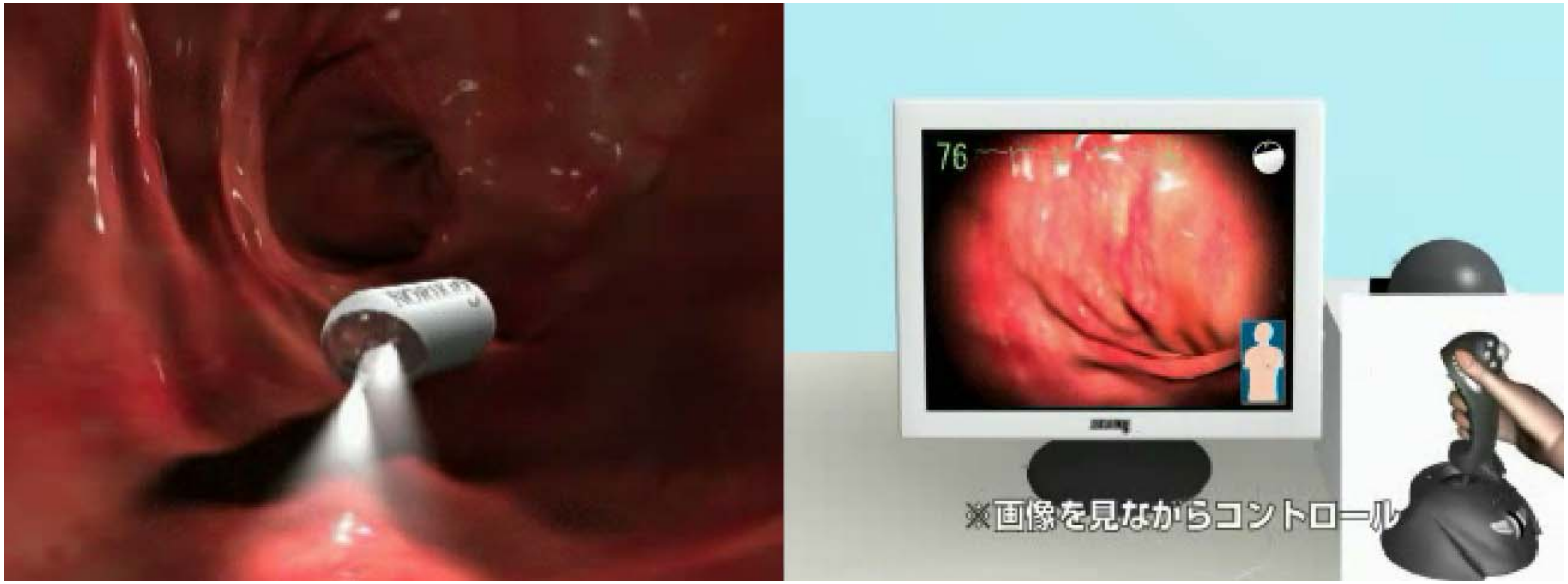
Courtesy of ***InTouch Health***

New Generation : Humanoid ?

Honda (Japan)

ircad

New Generation : MicroRobot



Norika (Korea)

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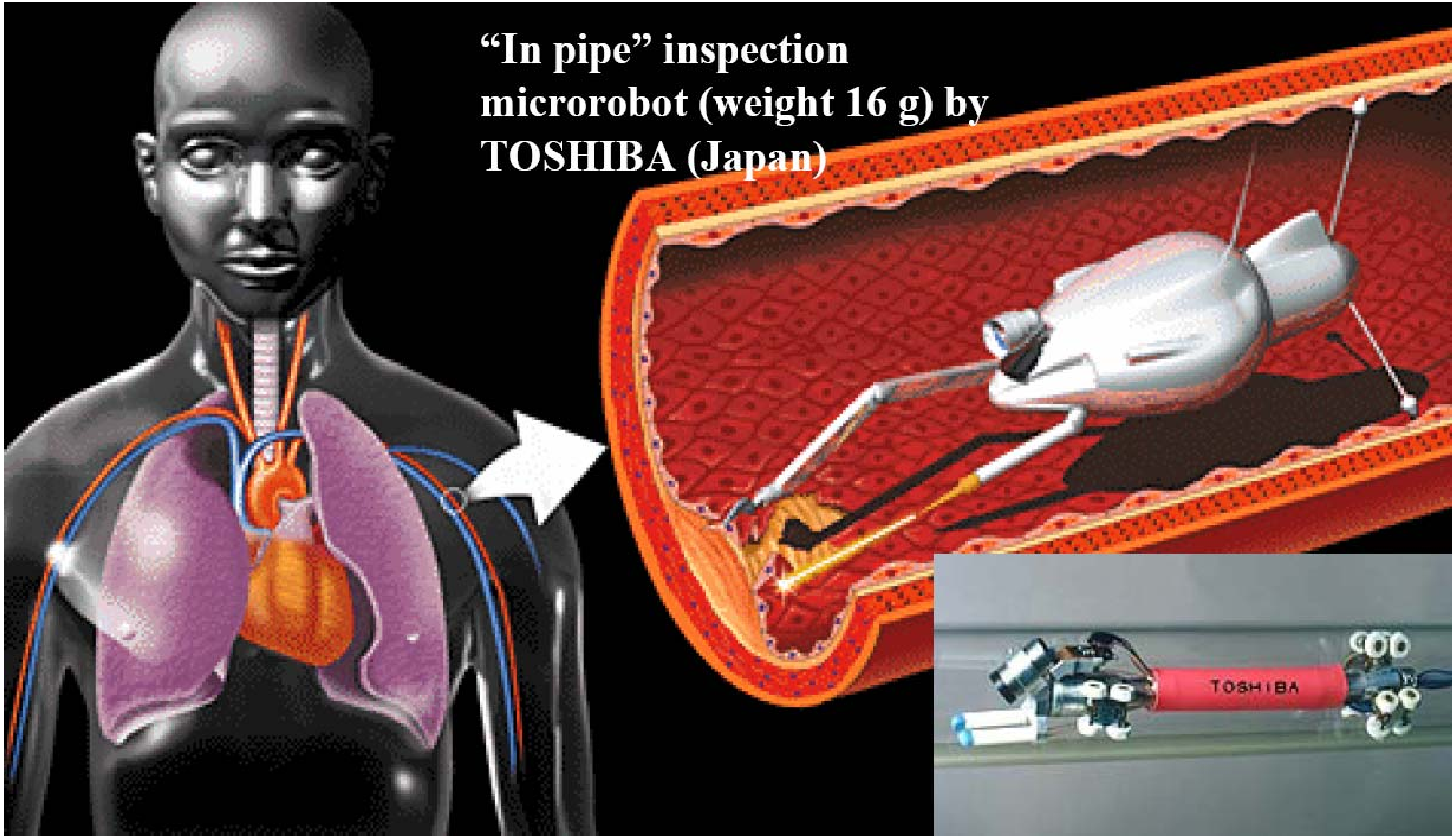
Next Generation : MicroRobot



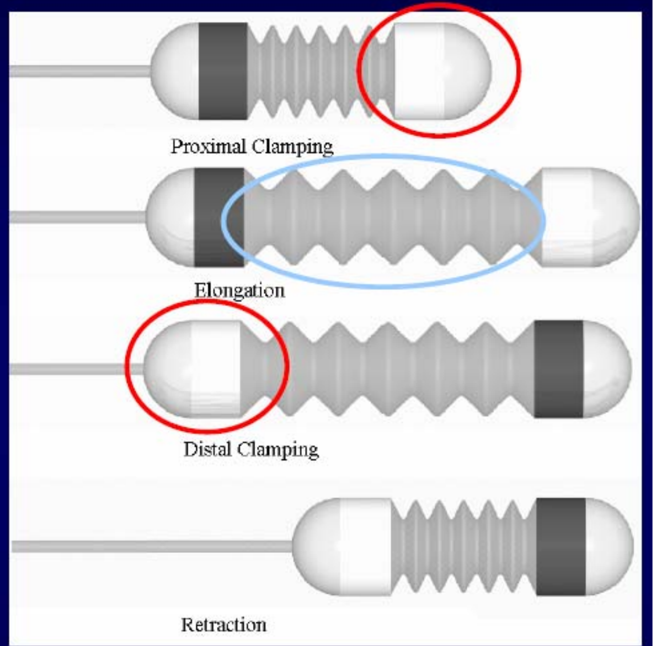
Toshiba (Japan)

Next Generation : Biomimetic Robot

Distal clamper

Central elongator

Proximal clamper



Typical colonoscopy prototype

Diameter : 24 mm

Retracted Length : 115 mm

Elongated Length : 195 mm

Stroke: 80 mm

Inteligent Microsystem Center (Korea)

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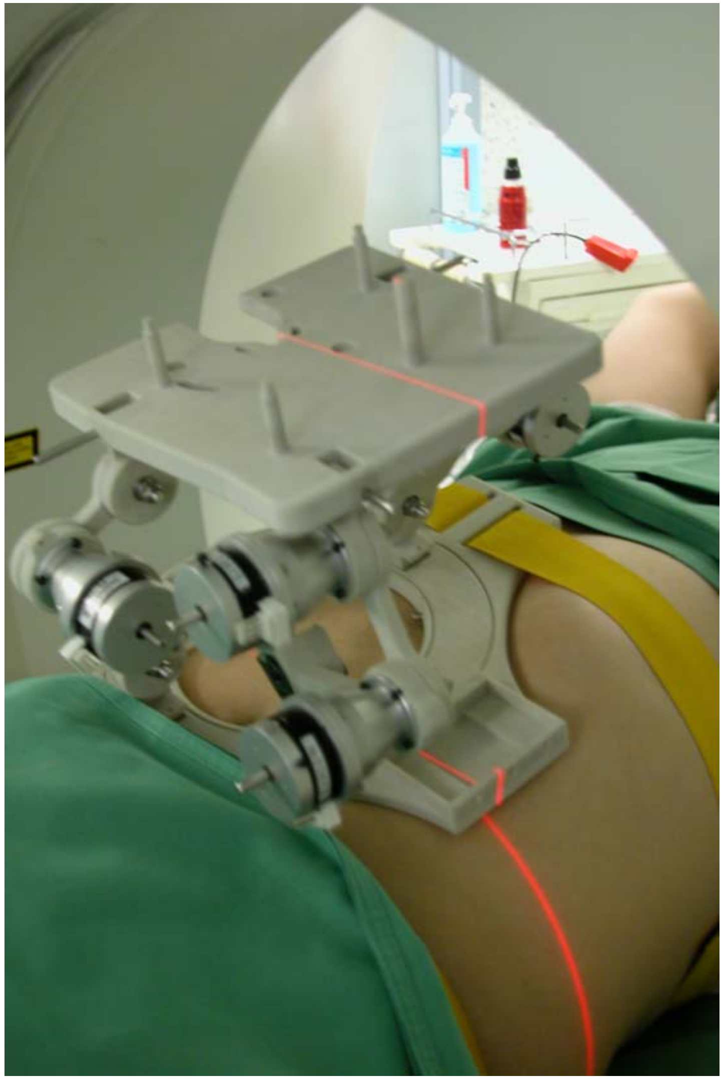
New Generation : smallest



CTBot:

- **7 DOF positioning robot**
- **Automatic needle placement**
- **Automatic needle release**
- **Force sensors**

Percutaneous needle insertion robot

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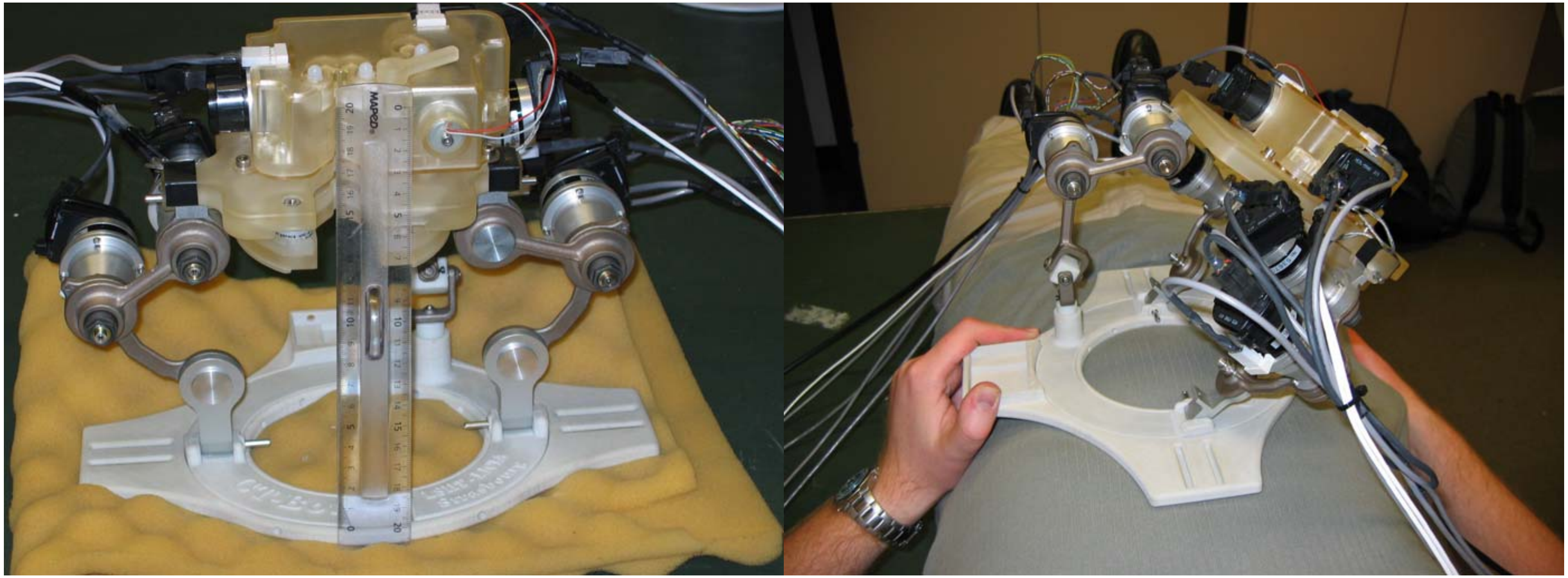
New Generation : smallest

CT-Bot



Percutaneous needle insertion robot

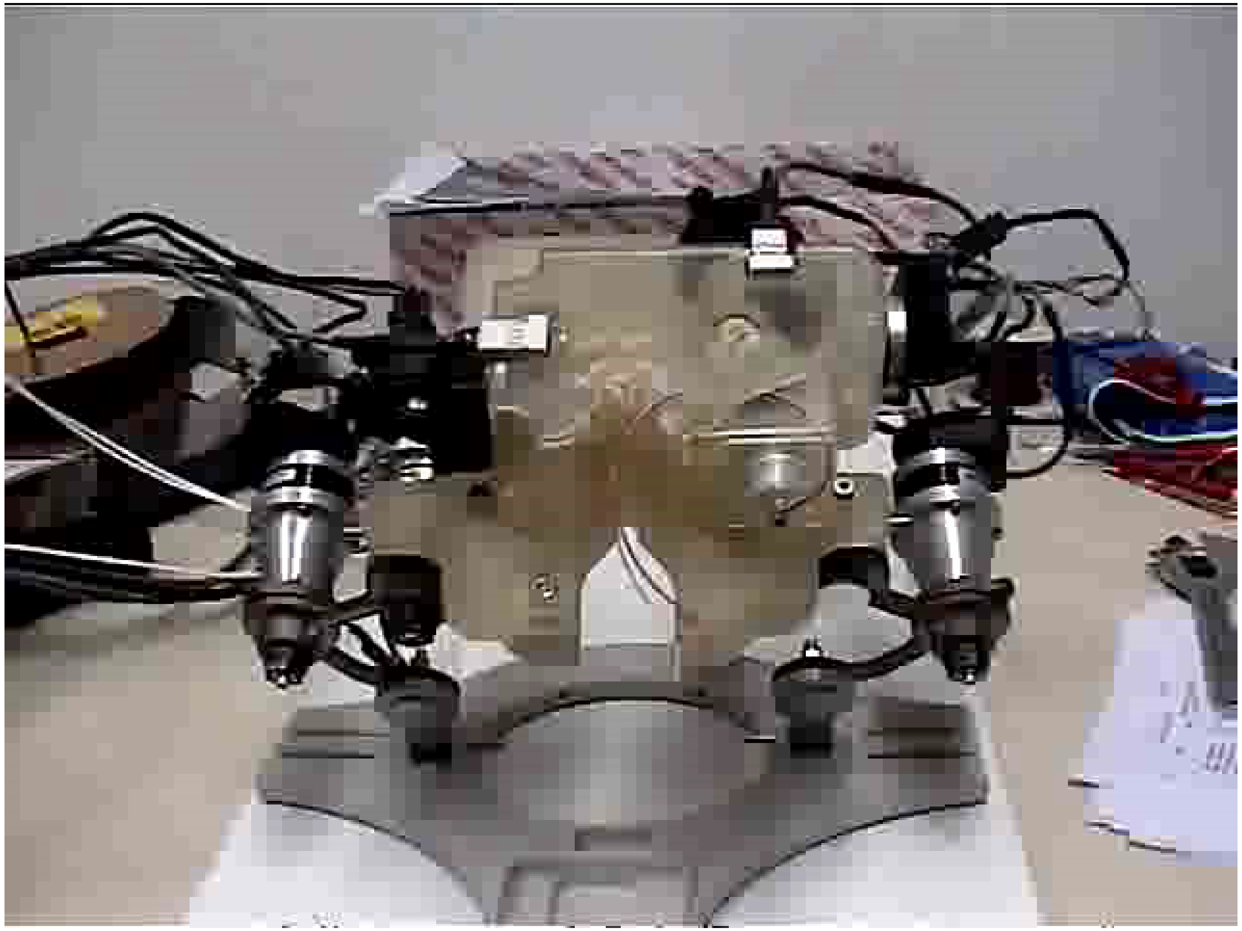
New Generation : smallest

CT-Bot

Percutaneous needle insertion robot

New Generation : smallest

CT-Bot



Percutaneous needle insertion robot

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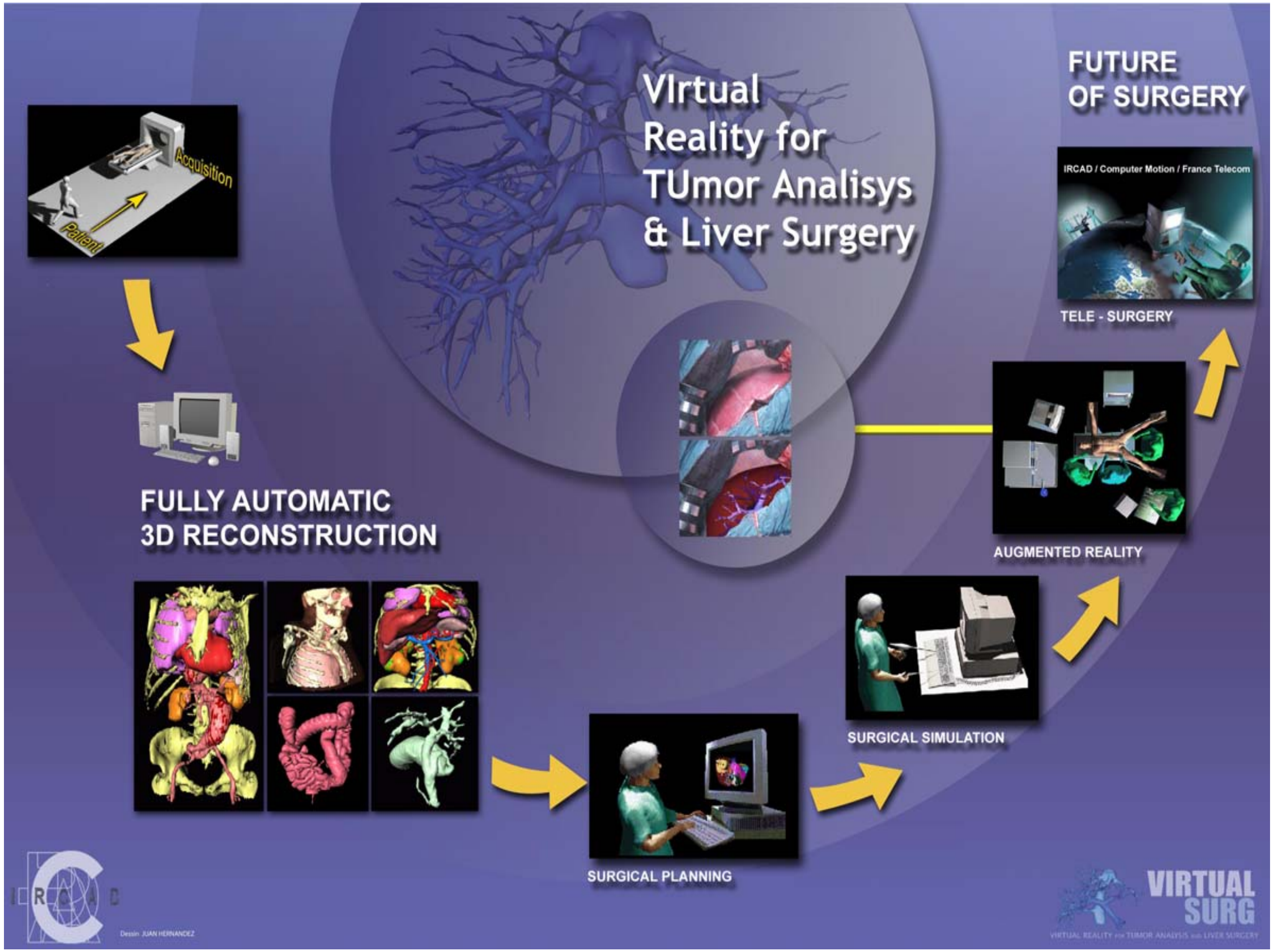
Conclusion : Future = Automation



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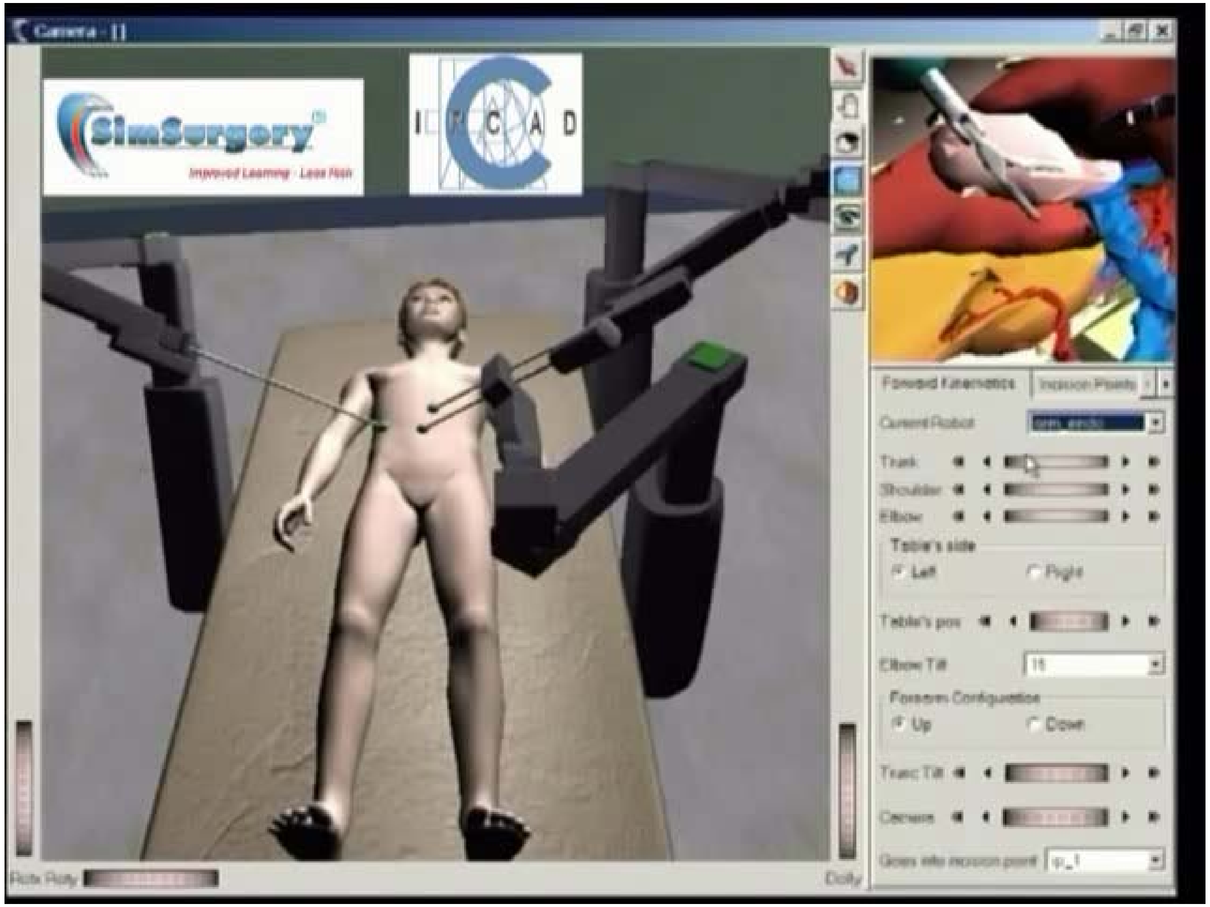
Combine Virtual Reality & Robotics

Robotic Surgical planning



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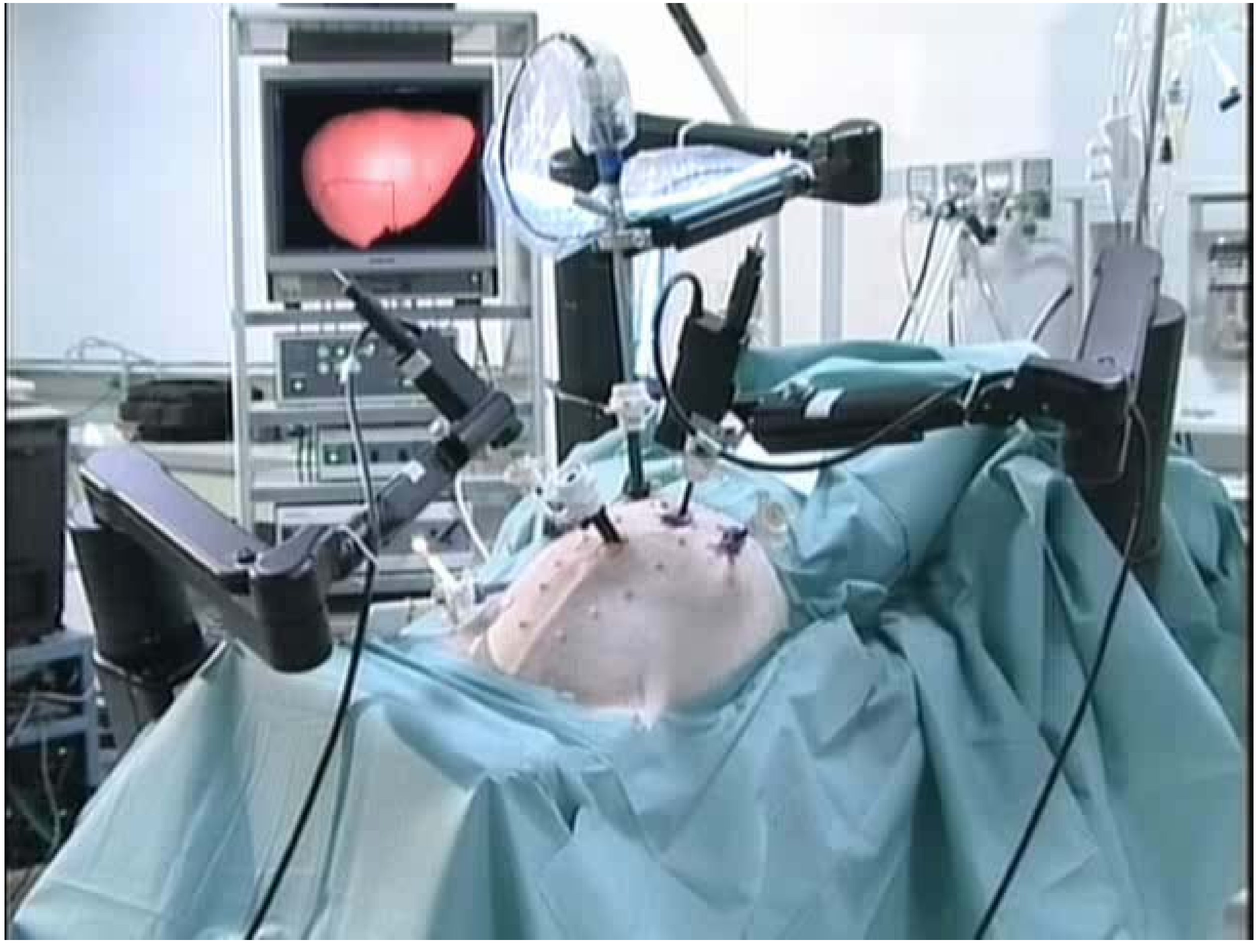
Combine Simulation & Robotics

Robotic Surgical Simulation

Augmented Reality and Robotics

Future of surgery ?…

Automated procedure



Conclusion

Is Fully automation possible ?

Certainly Yes in a near future

But Is it wanted ?

What about the Ethical issue ?