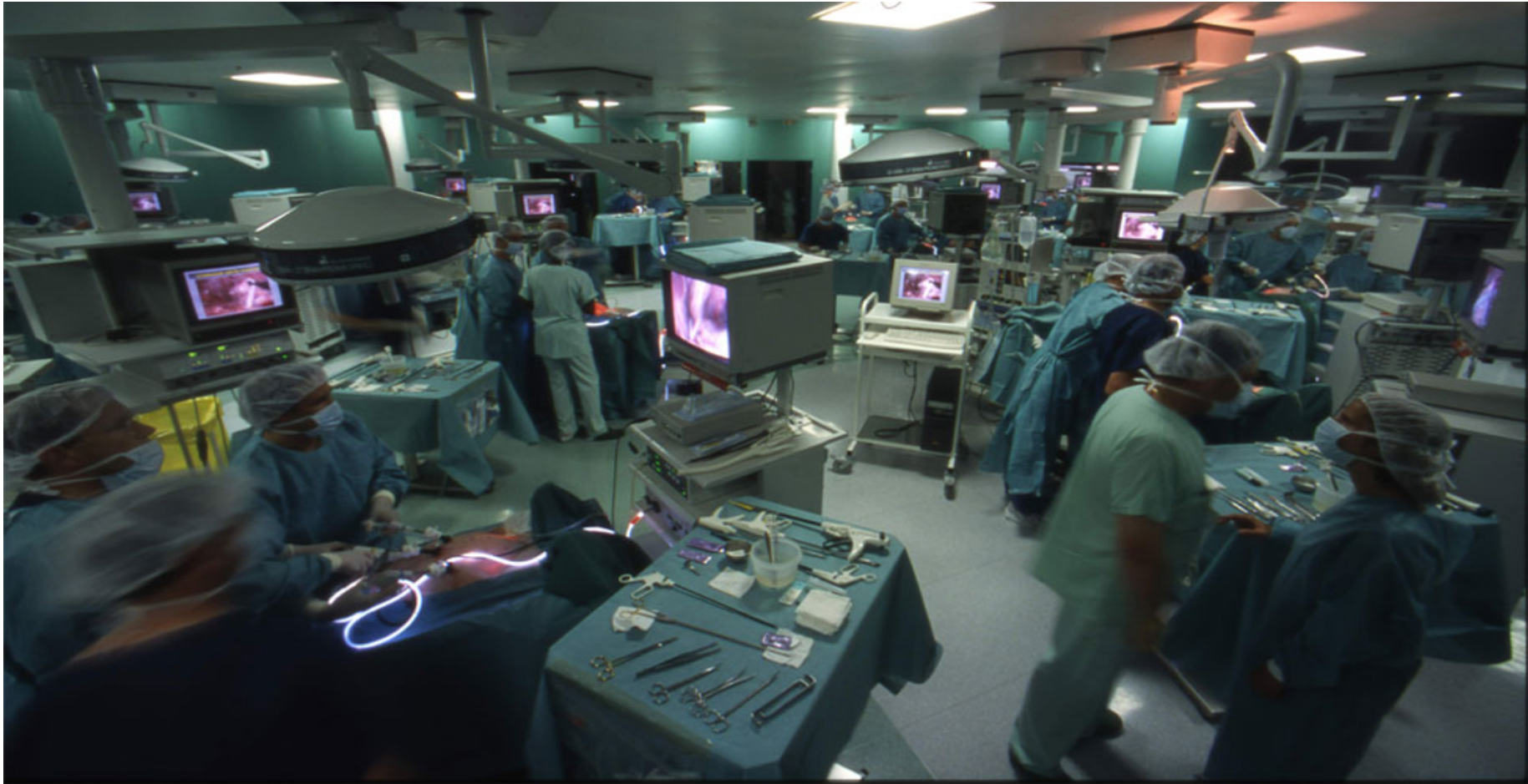


# Virtual Reality and Robotics in Digestive Surgery

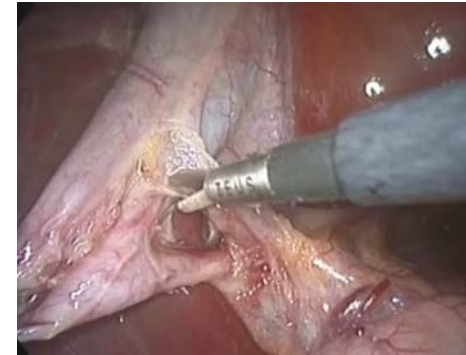
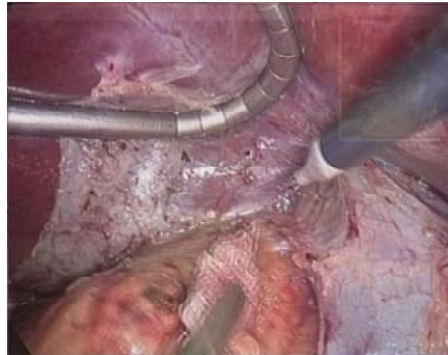
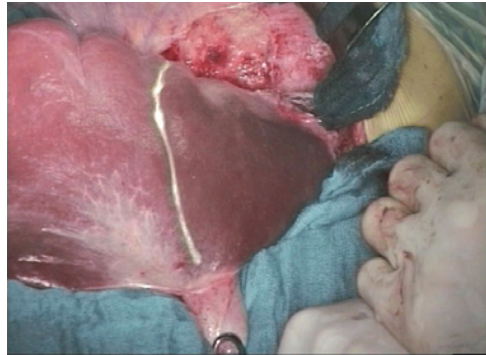


**Pr. Luc Soler, Pr. Jacques Marescaux**

**ircad**

# 20<sup>th</sup> century Surgical Evolution

Open → Laparoscopy → Robotics



*New vision of surgery*

**ircad**



# WebSurg : Continuous education

## I. Web site

The screenshot displays the WebSurg website interface as of February 9, 2005. The top navigation bar includes categories such as GENERAL AND DIGESTIVE SURGERY, ENDOCRINE SURGERY, PEDIATRIC SURGERY, THORACIC SURGERY, UROLOGY, GYNECOLOGY, CARDIOVASCULAR SURGERY, and EQUIPMENT SURGERY. The main content area is titled "WebSurg's World Virtual University" and features a search engine, "Operative technique chapters" (e.g., Transperitoneal laparoscopic radical nephrectomy), and "11 New Videos in Laparoscopic Surgery" with a list of procedures like Virtual colonoscopy and Laparoscopic cholecystectomy. The right sidebar contains a "Table of contents" section with a search filter and a list of topics including Adrenal glands, Bladder, Kidney and ureter, Pelvis, and Prostate, each with associated article counts. The footer contains the URL <http://www.websurg.com> and the Ircad logo.

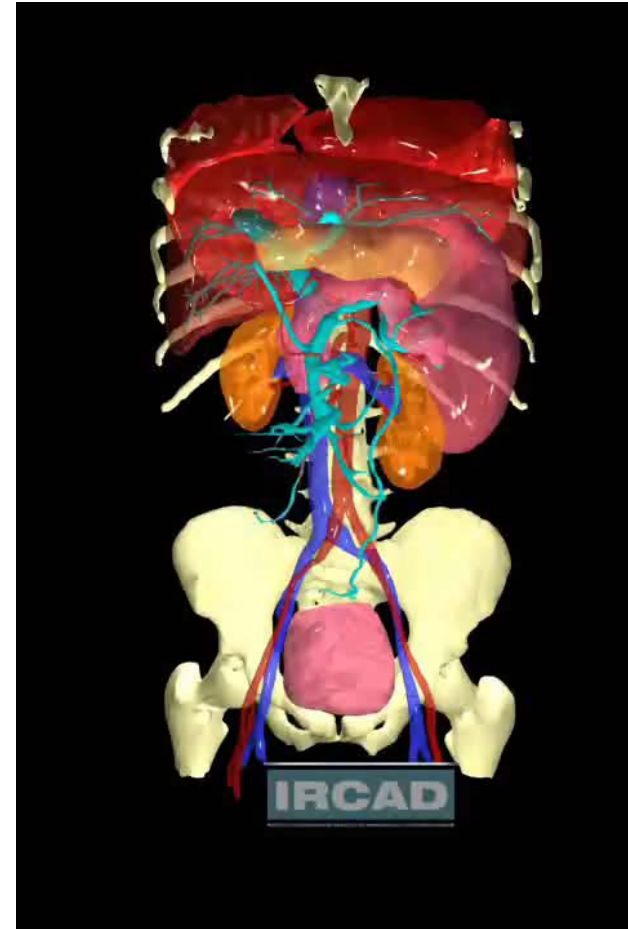
<http://www.websurg.com>

**Totally FREE !...**



# 20<sup>th</sup> century Imaging revolution

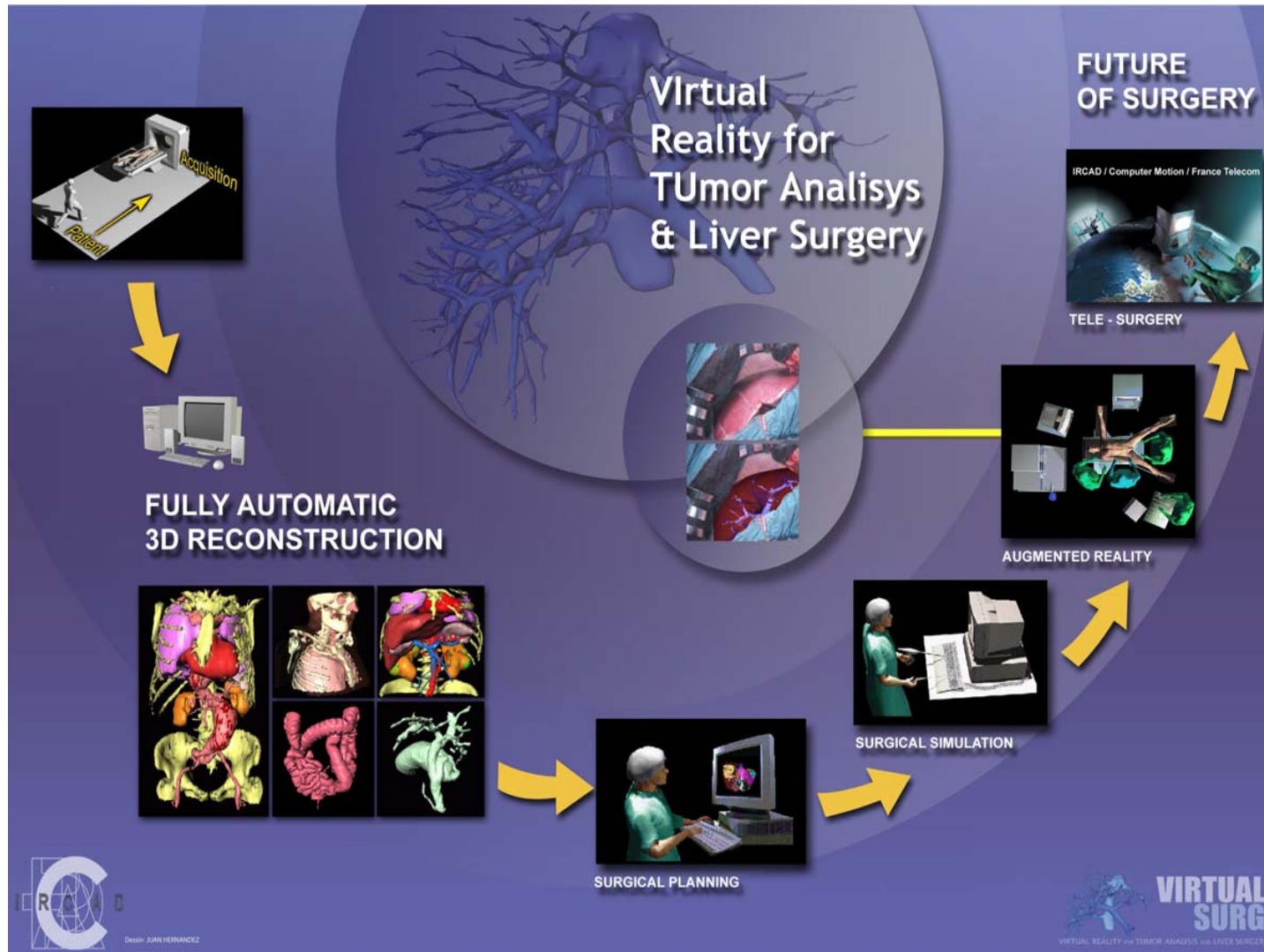
2D slices → 3D virtual patient



*New vision of the patient*

**ircad**

# A global approach



From Image to Computer assisted Surgery

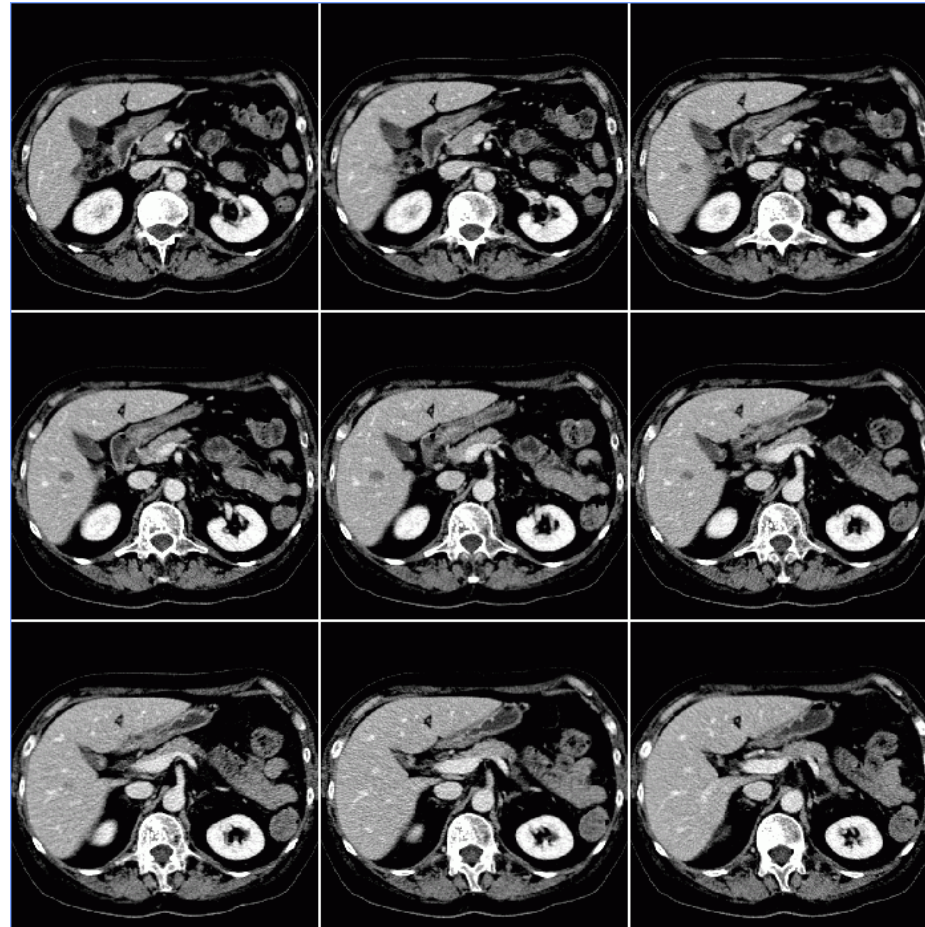




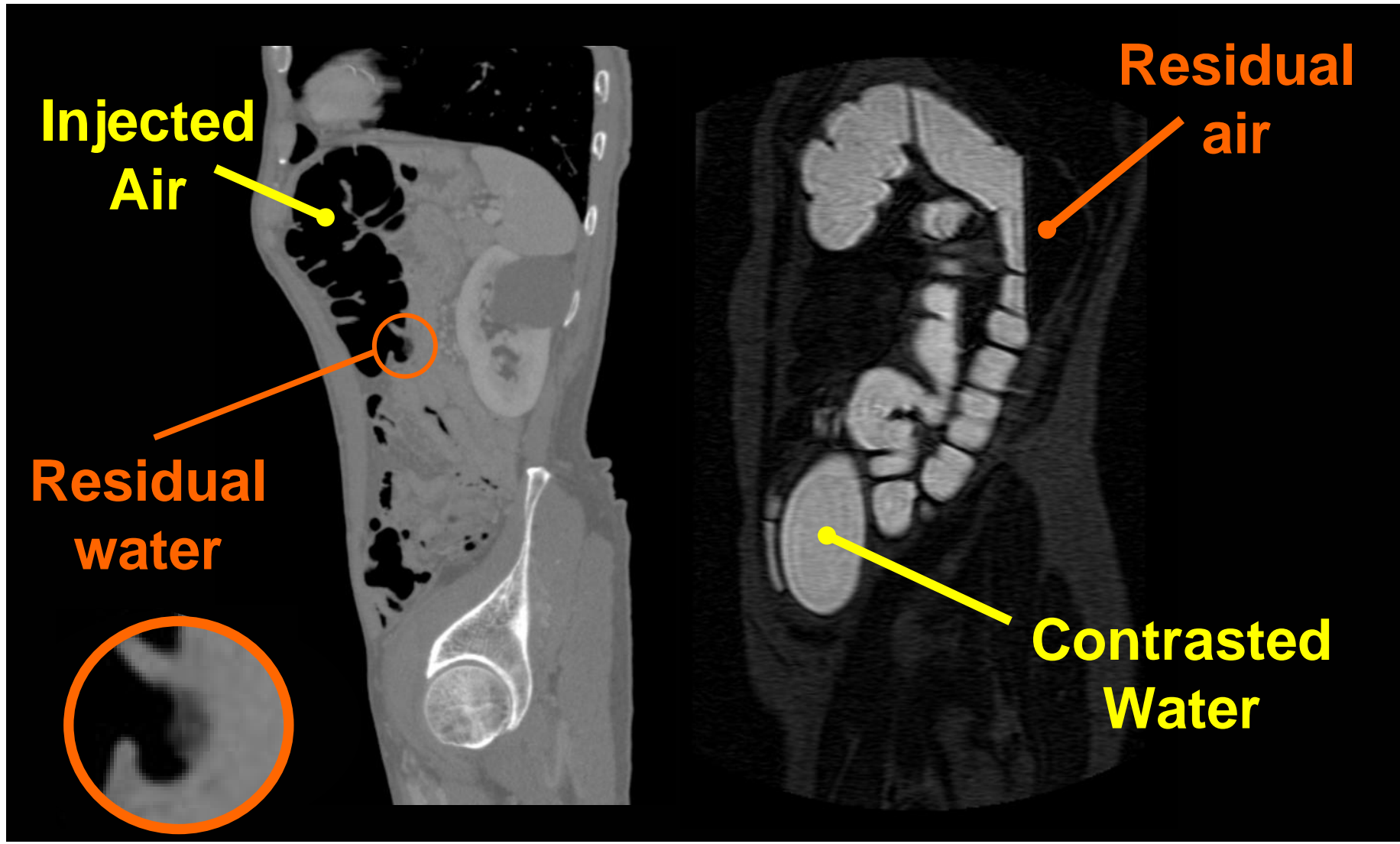
# First Step : 3D Modeling of patient

6

## From CT-scan or MRI of a patient



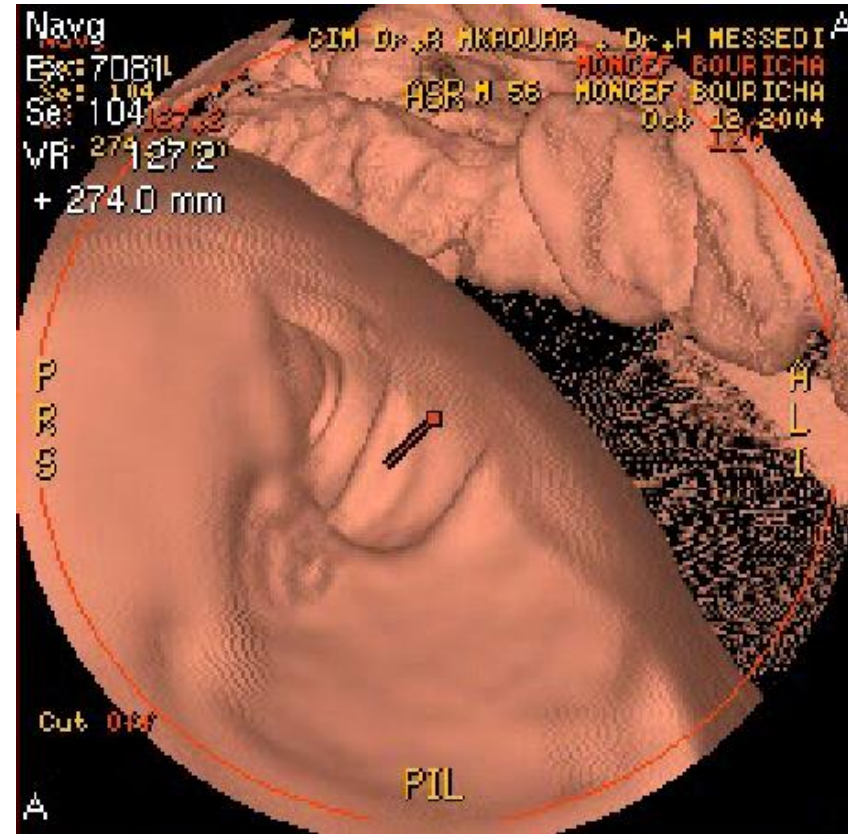
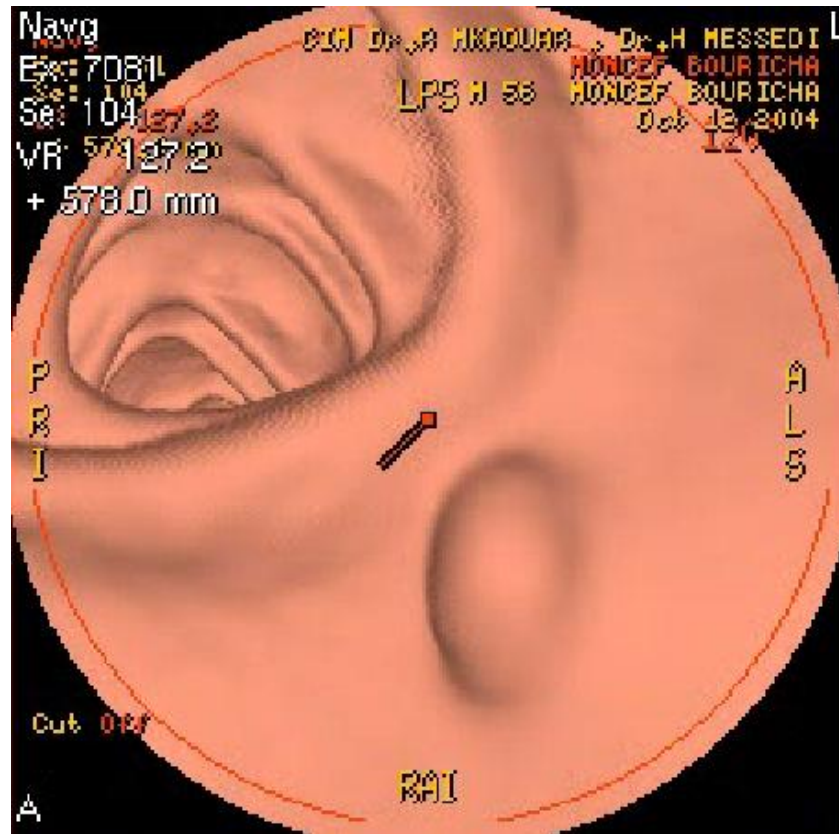
# First Step : 3D Modeling of patient



CT-Scan or MRI

# Ray Tracing : Virtual navigation

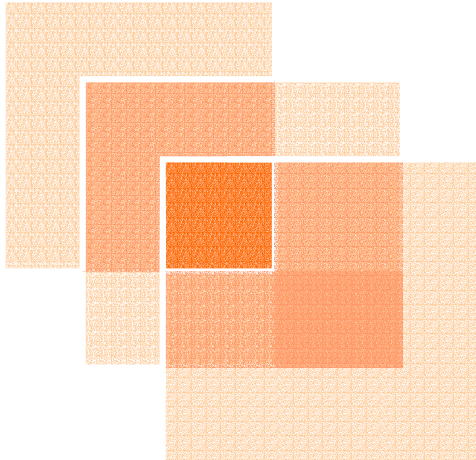
Nice 3D vision, but no real delineation  
Quality depends of good parameterization



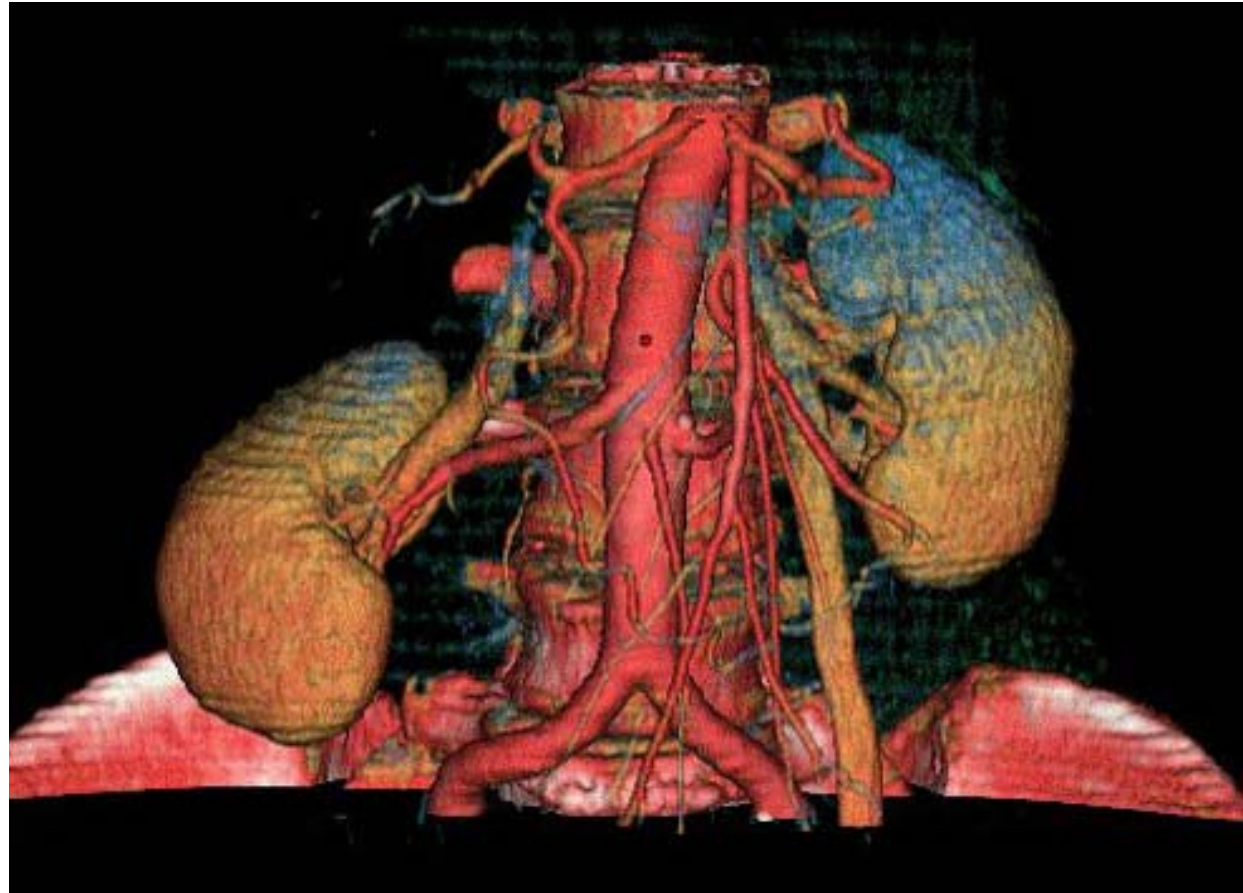
Ray Tracing Limited to lumen vision



# Volume Rendering : vessels in 3D



**Transparency of voxels without  
Delineation of Structures**



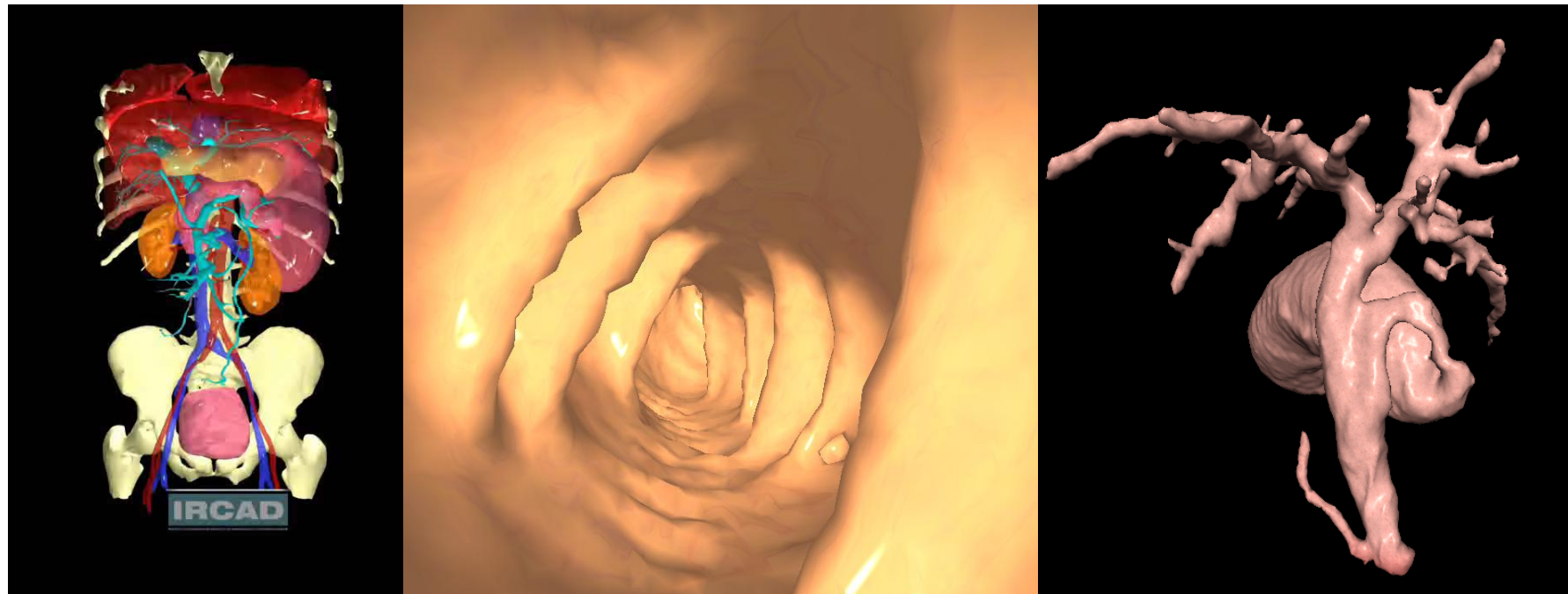
**Volume rendering**

**Limited to 3D visualization**

**ircad**

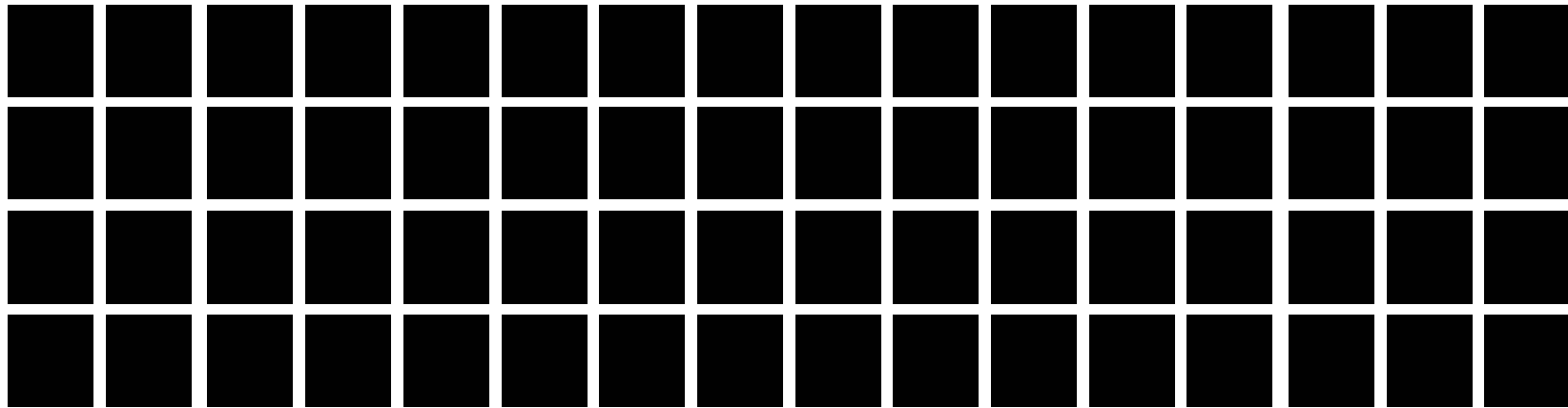
# Surface Rendering

- 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 Irie 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**



**Thresholding  
Filtering  
Gradient**

**Distance  
Map and  
Constraints**

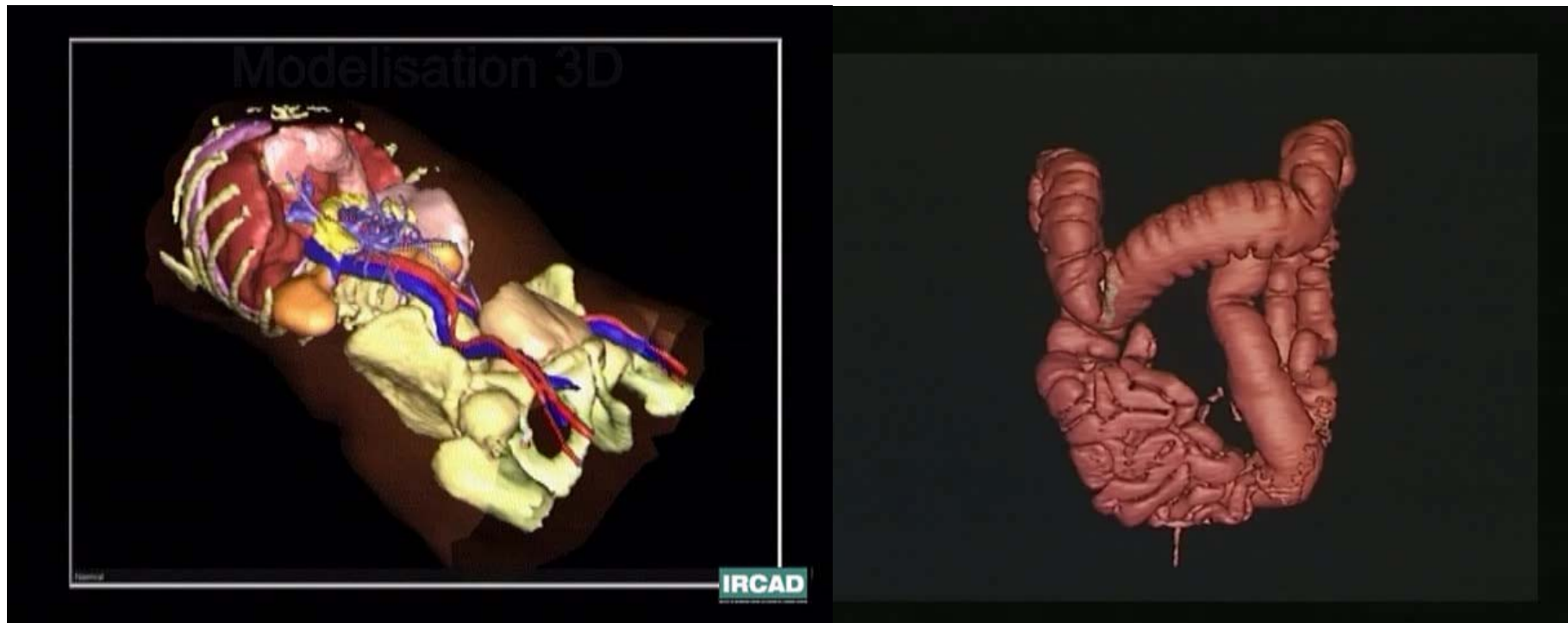
**Morphology  
+Geometrical  
Constraints**

**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**

**ircad**



# First Step : 3D Modeling of patient

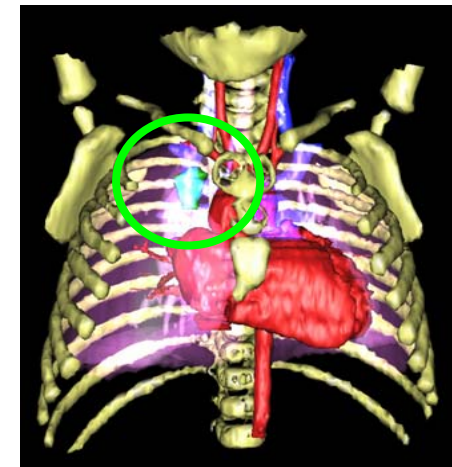
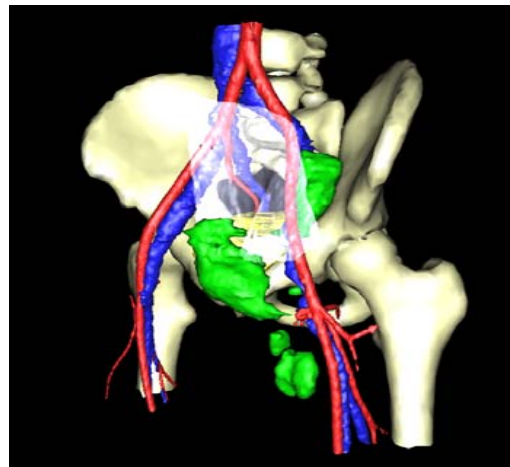
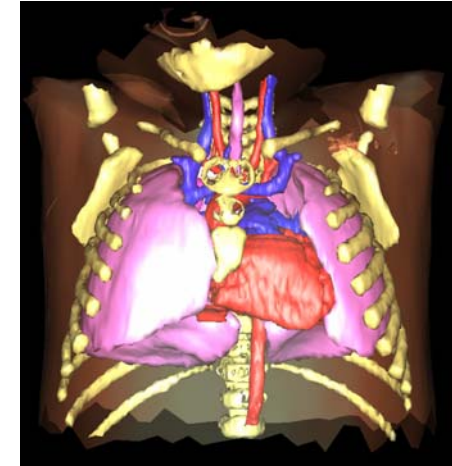
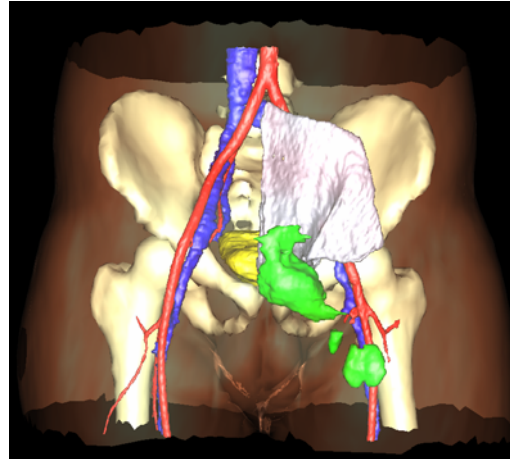
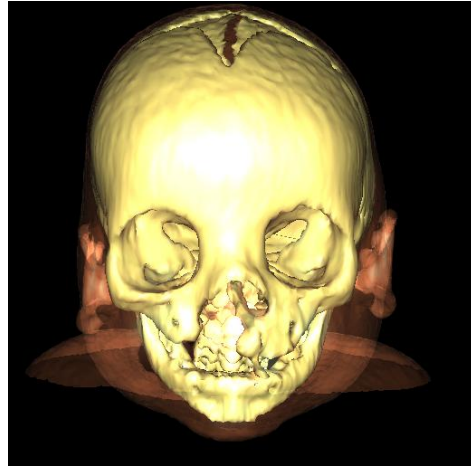
15



*Used for liver surgery*

**ircad**

# 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 ...

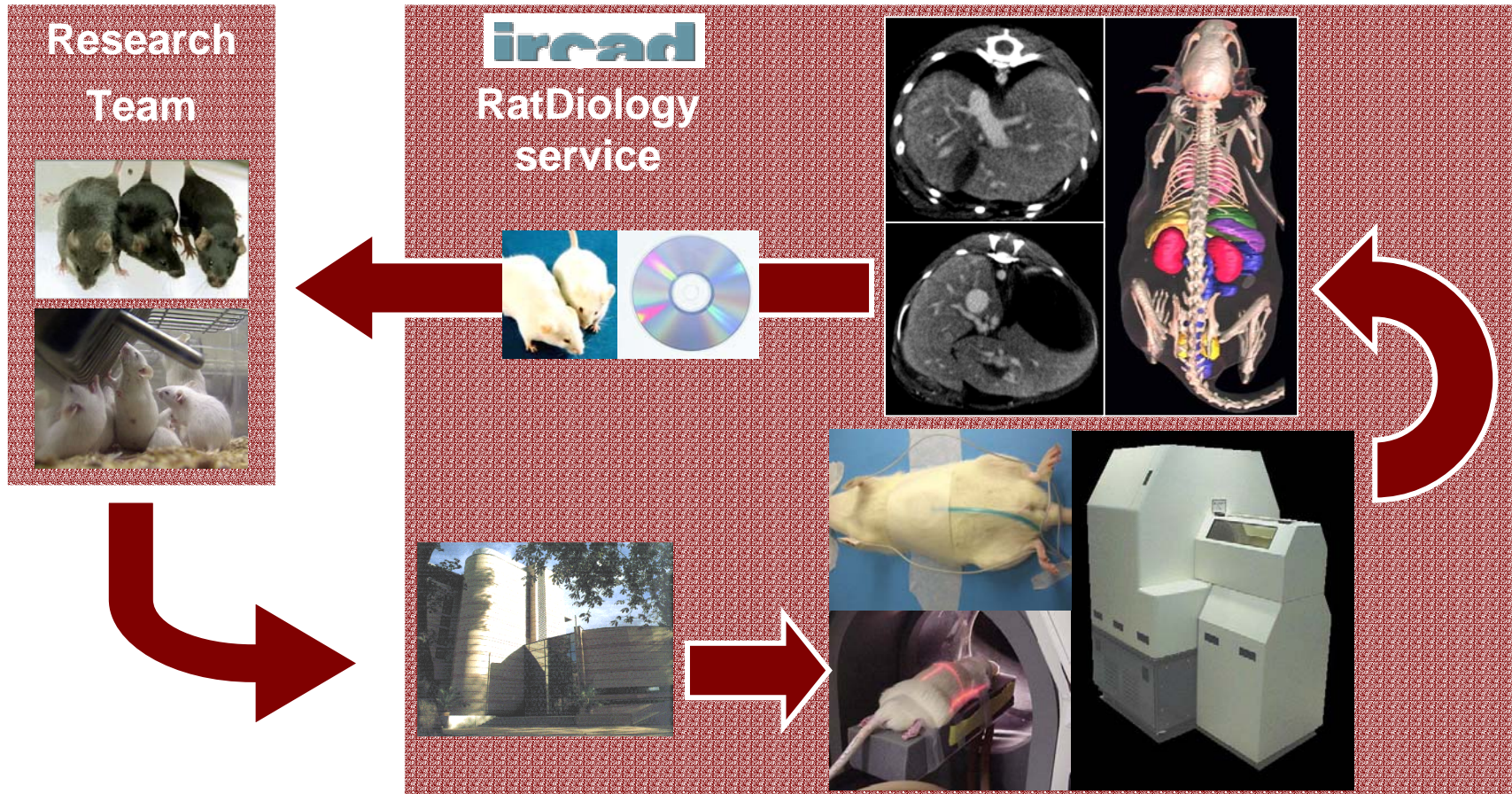
**Is 3D Modeling in 15 mn feasible ?**

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

**Sample : stomach et pancreas in abdominal image of the liver**

# New tool for fundamental research

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



# IRCAD's Micro CT-scanner

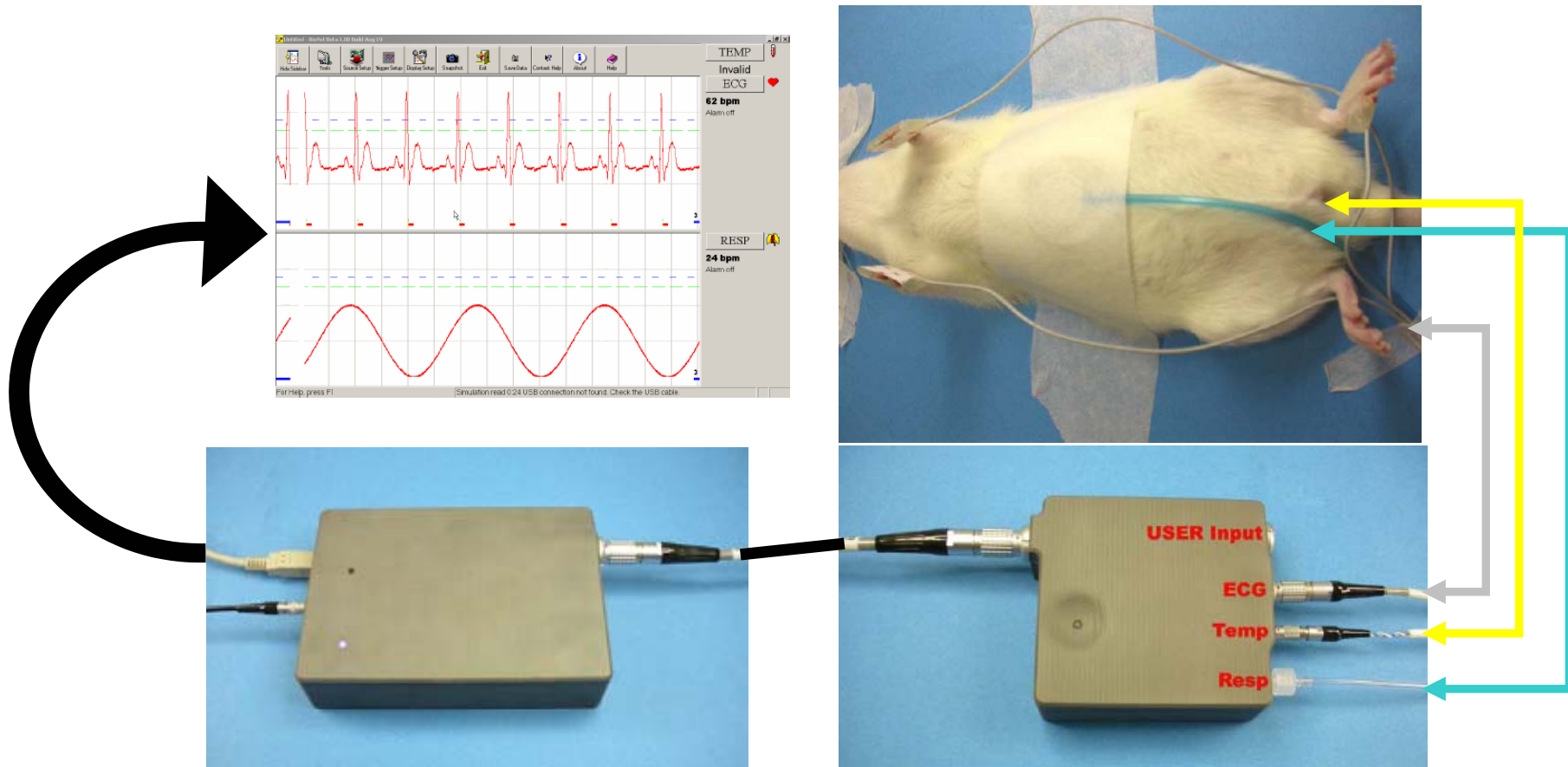


*Région Alsace, Département Bas-Rhin, Ville de Strasbourg,  
Ligne Nationale contre le cancer*



# In vivo Micro scanner X

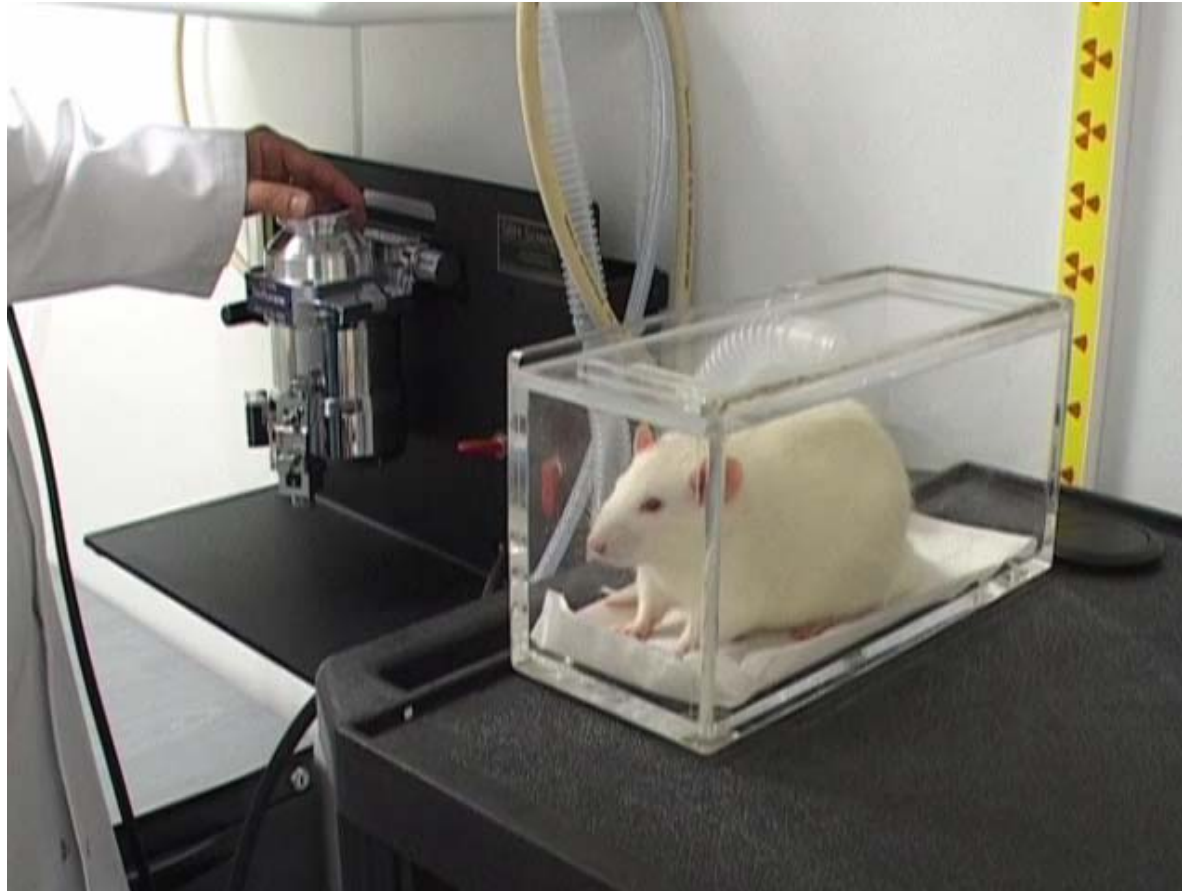
## Automatic Synchronisation





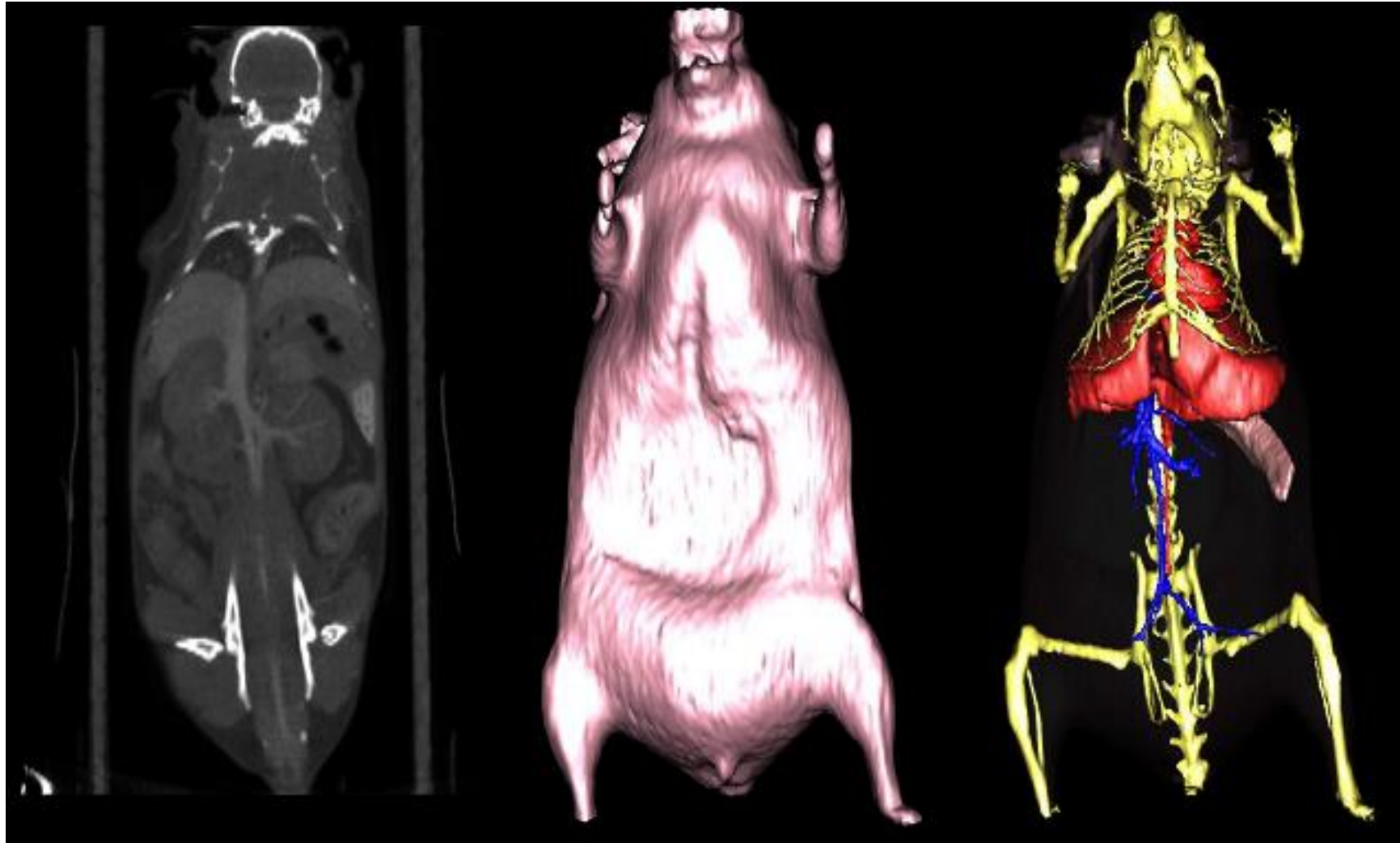
# New tool for fundamental research

## Air or Hexabrix or Telebrix : like human



*Keep the animal alive !...*

# New tool for fundamental research



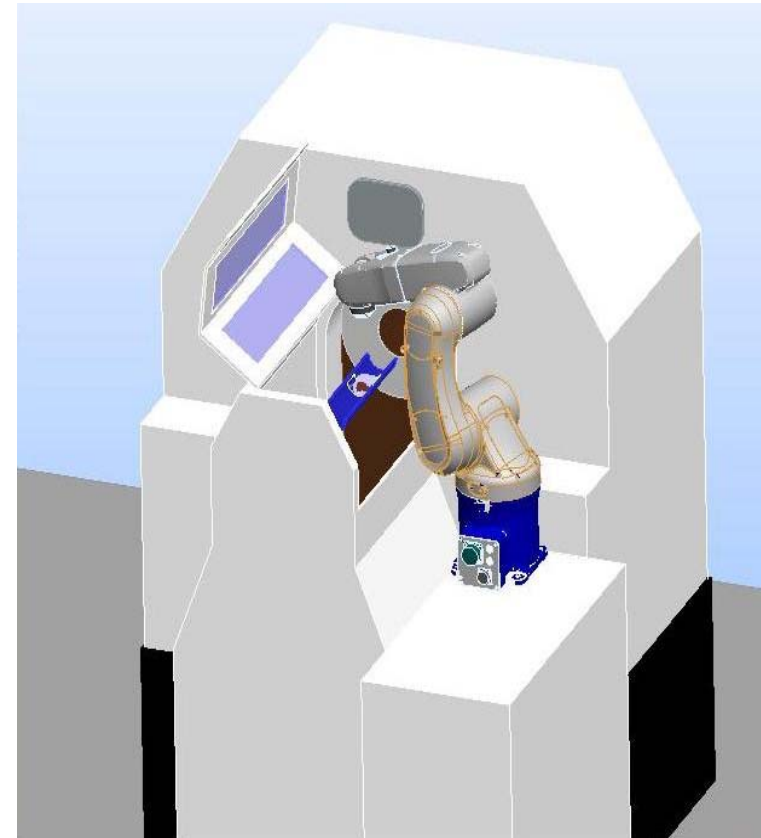
*Intravenous Fenestra LC + Fenestra VC*

**ircad**

# Robots for fundamental research



*VisualSonic Vevo Product*



*IRCAD/LSIIT Project*

*Robotised injection*

# Limits ...

**Is it the same automated segmentation than for human images ?**

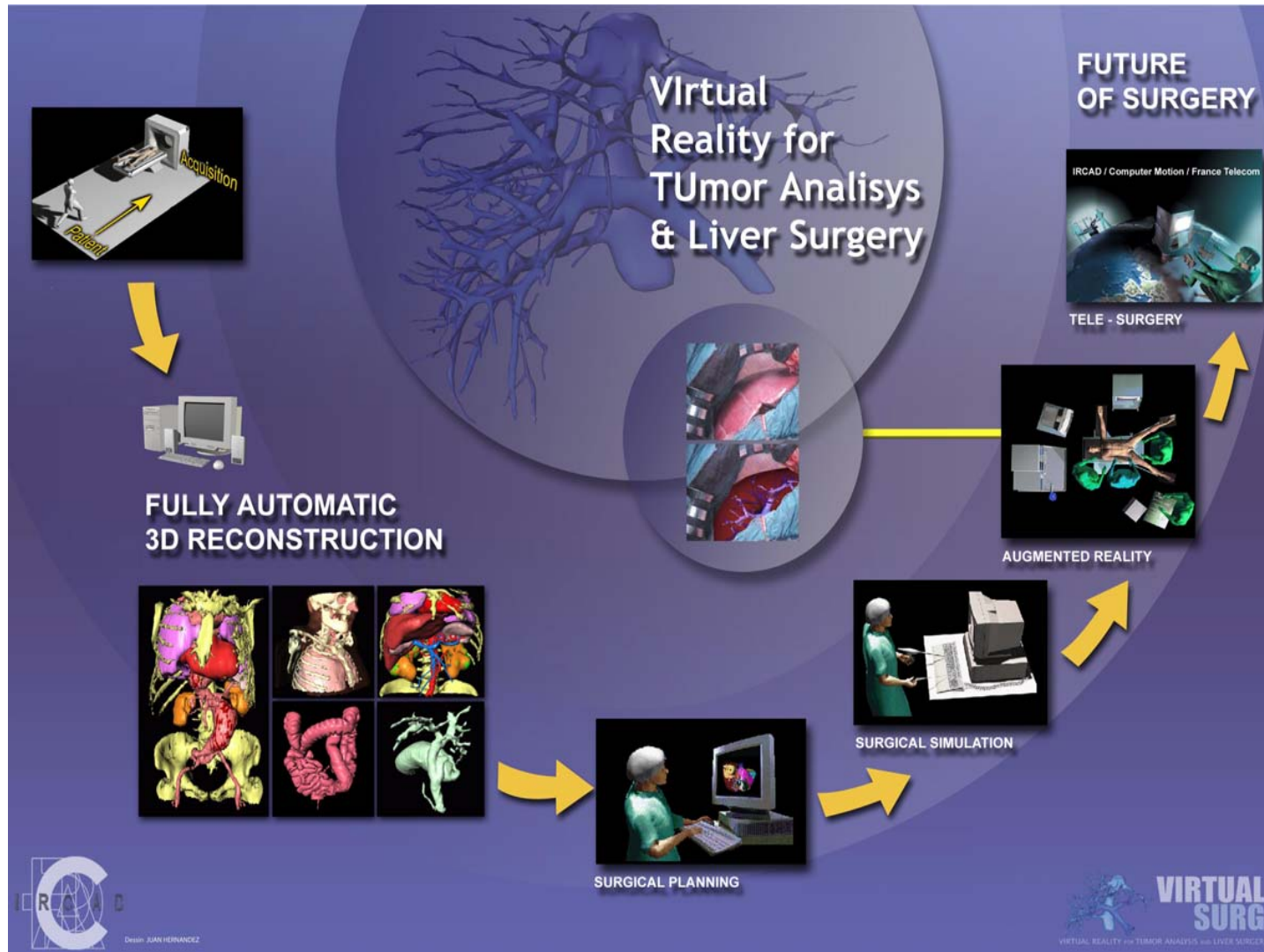
**No : Image and anatomy are different**

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

**Specific method can be easily developed**



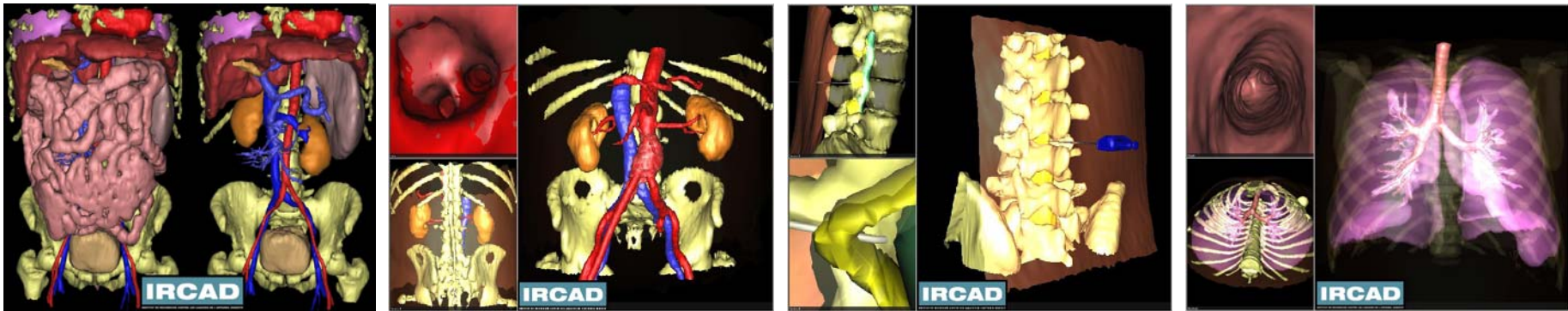
# Surgical Planning



# Second step : Surgical planning

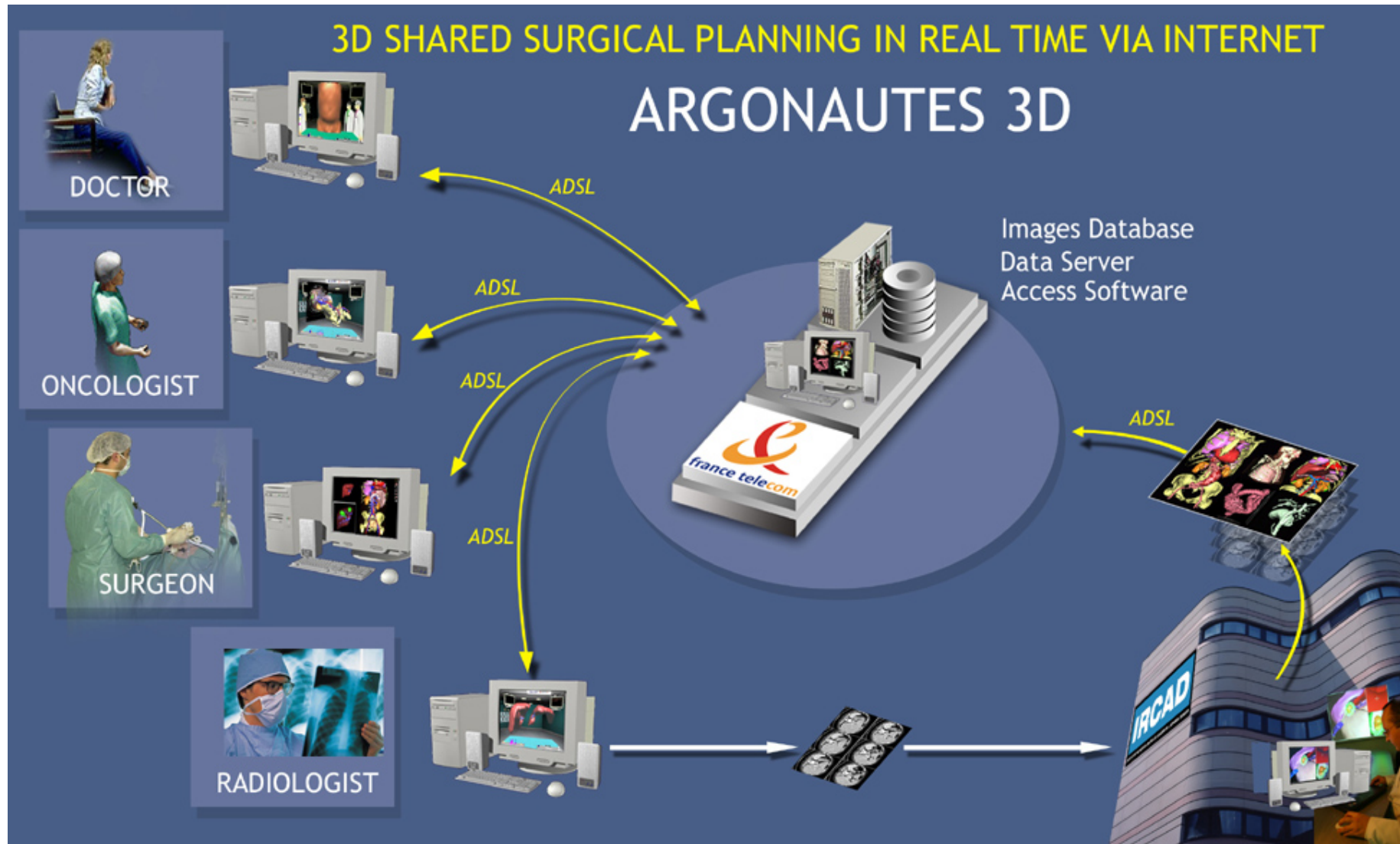
## Dedicated Software

### Working on a simple PC



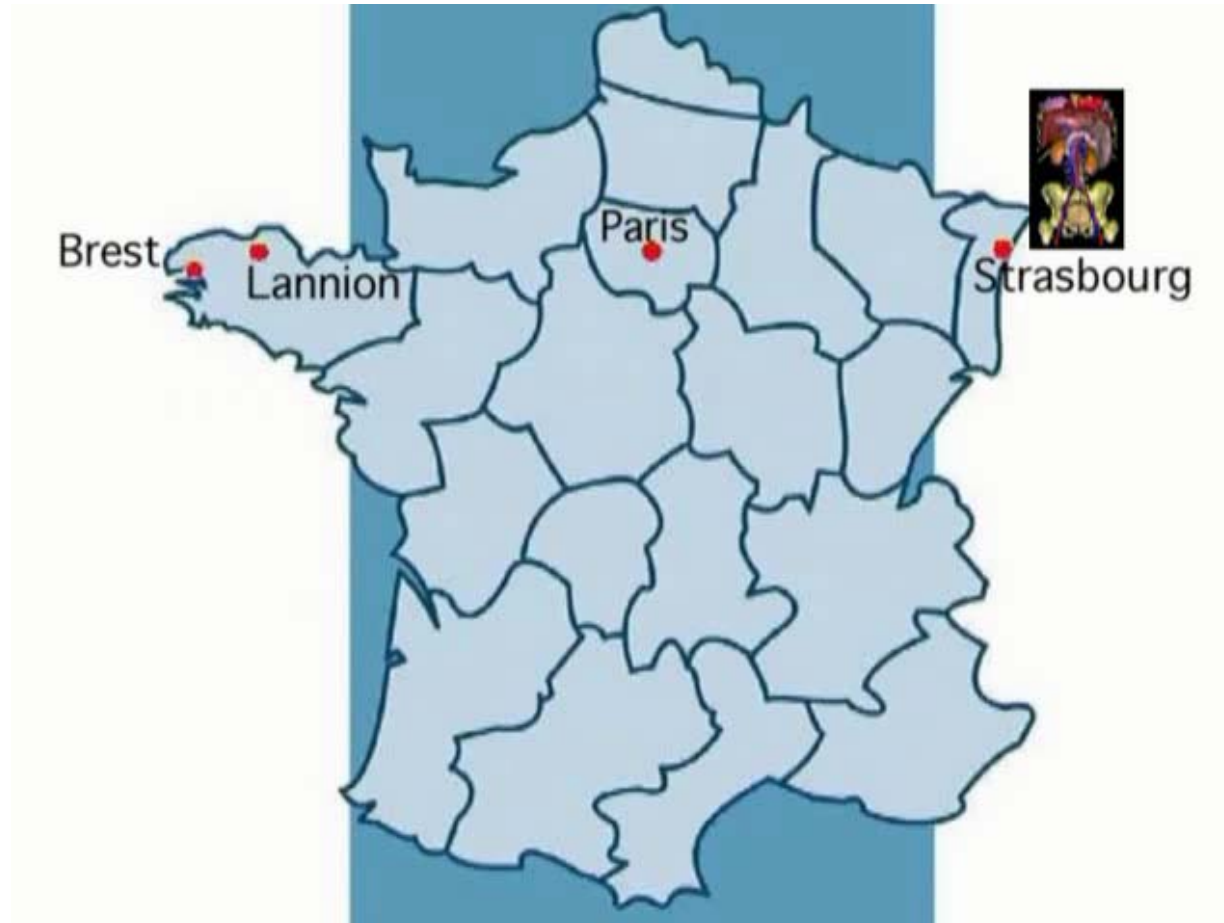
*Live demonstration*

# Second step : Surgical planning



# Second step : Surgical planning

5 novembre 2002 :





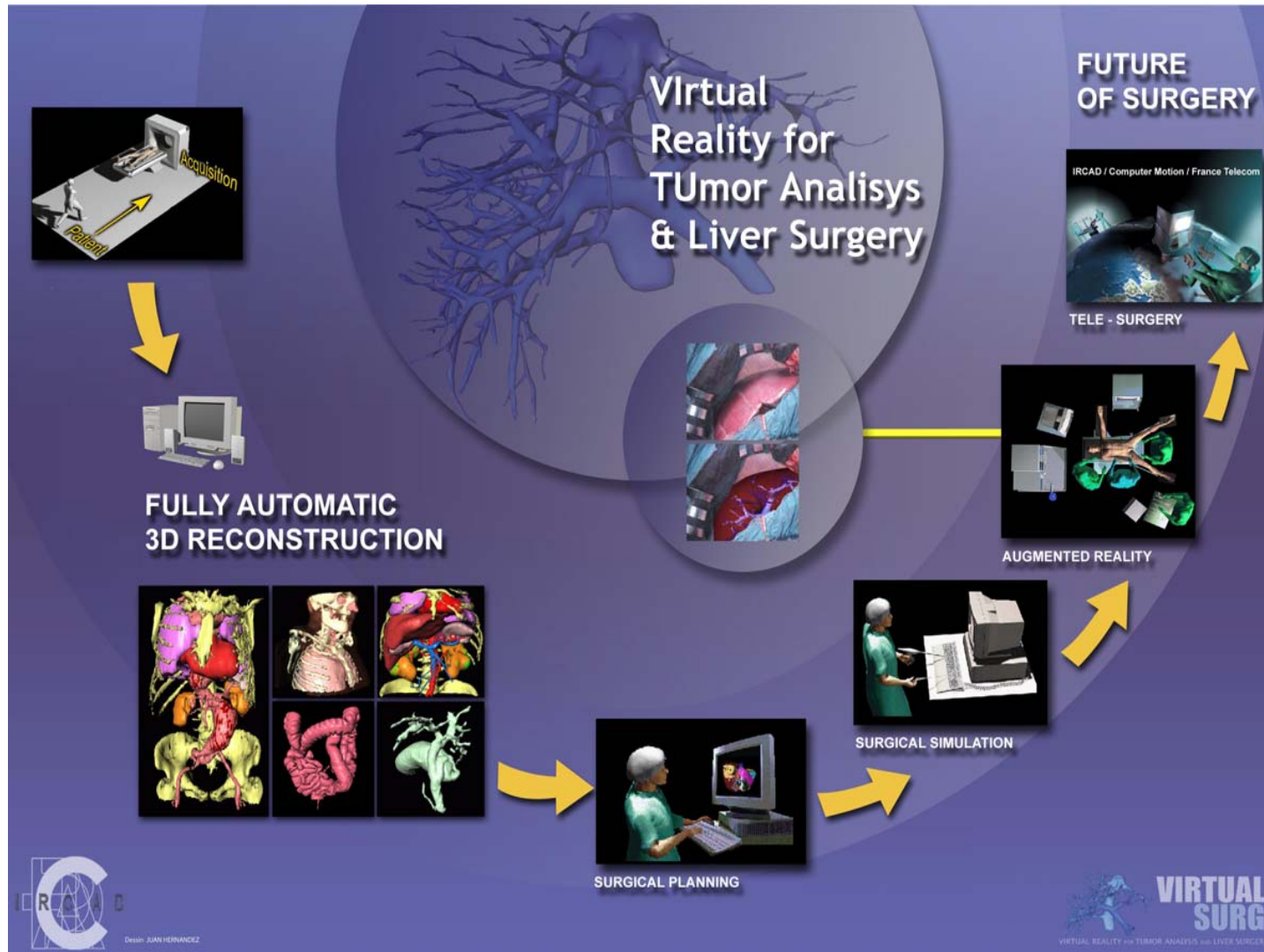
# Limits ...

**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

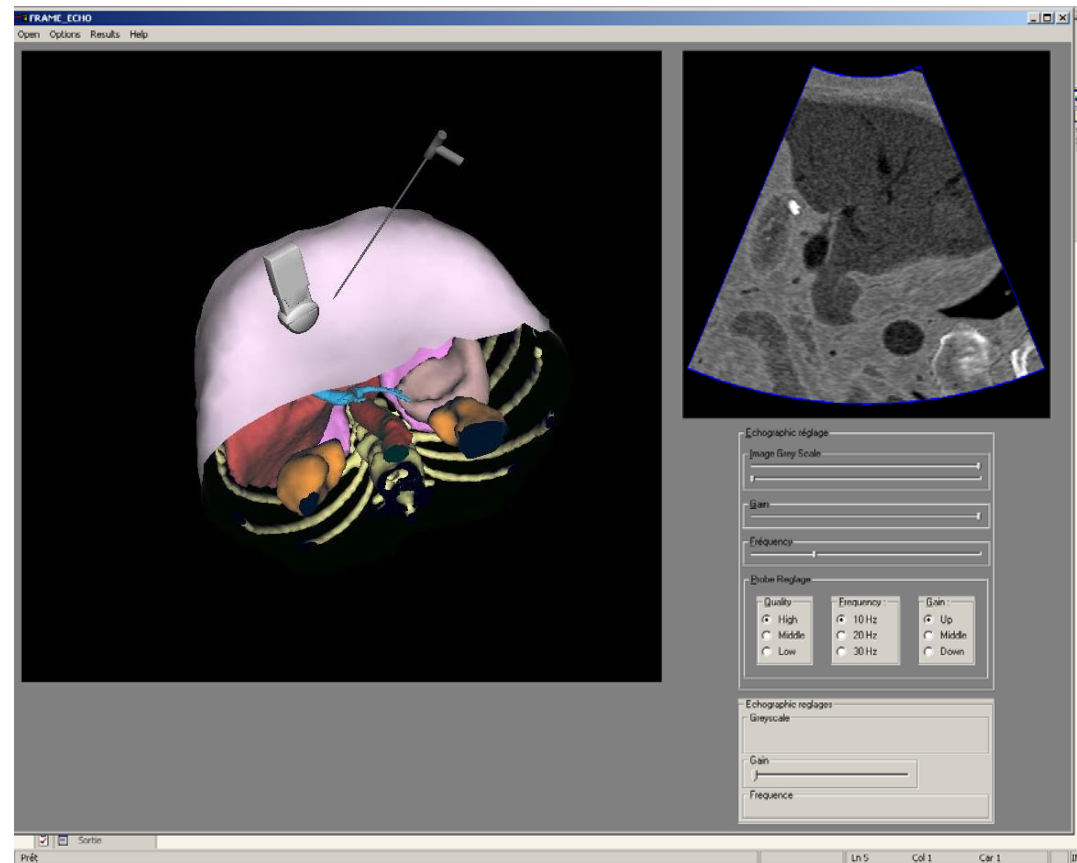


Where is the real ?



# 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



# Third Step : Surgical Simulation

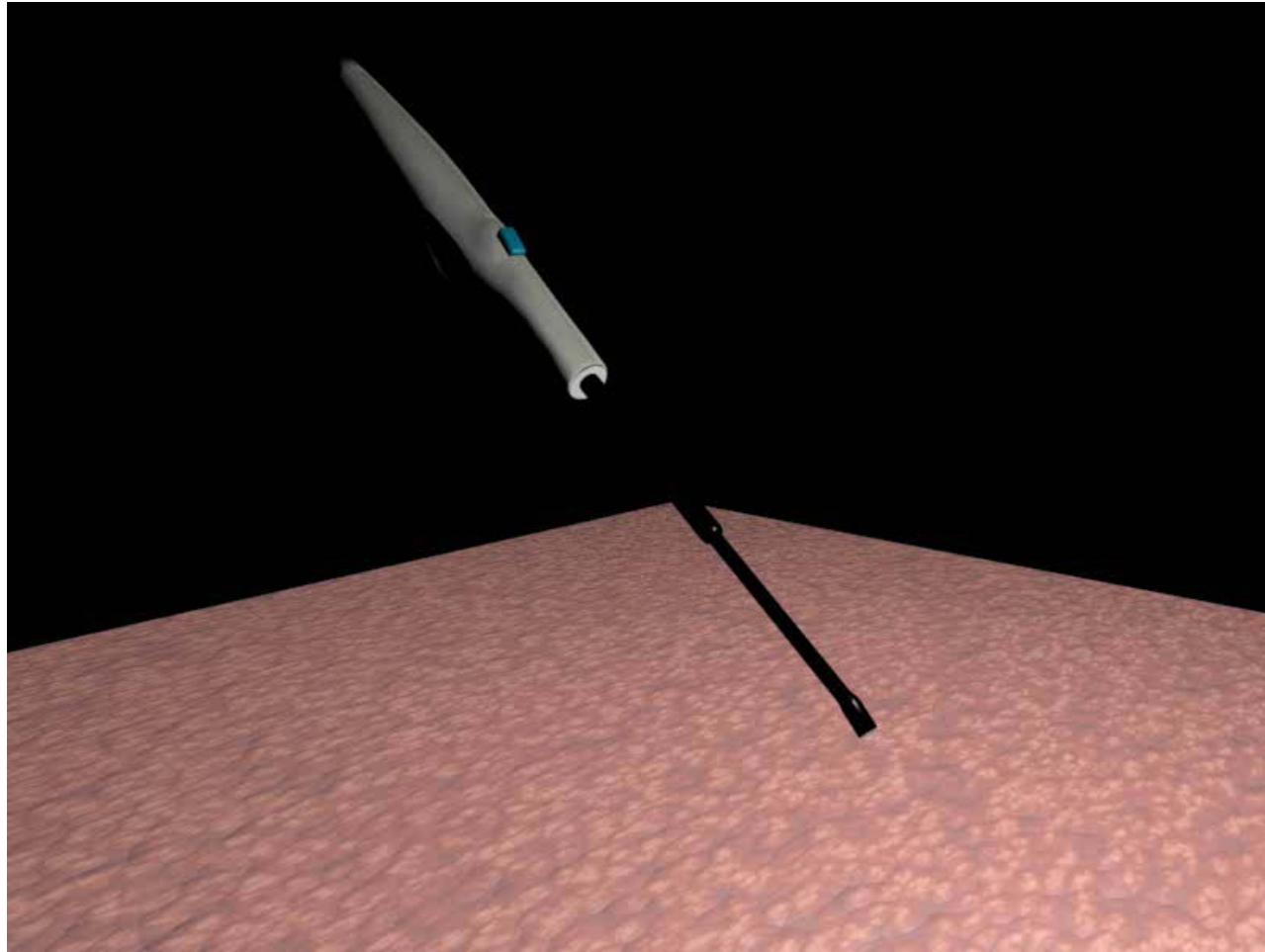
## Real-time Force feed-back simulation





# Surgical Simulation : ODYSSEUS

**Next Step : more realistic visual effects**



*ODYSSEUS Project : ULIS et SimLap*

**ircad**

# 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



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

# 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



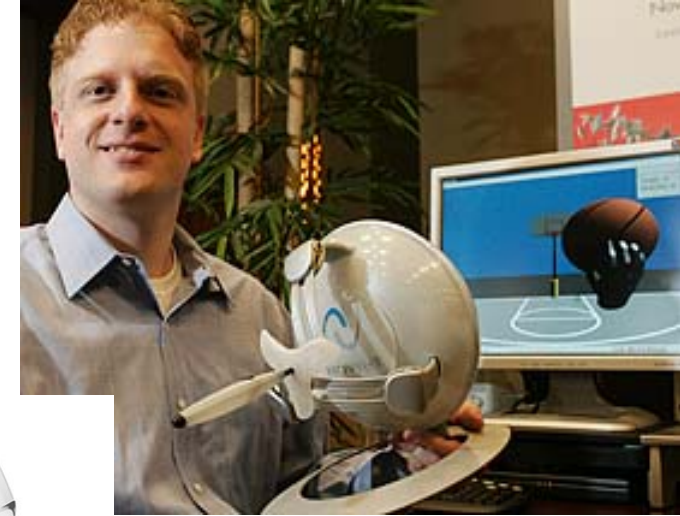
## 1 DOF FFB for endoscopy and catheter insertion



# New devices : low cost



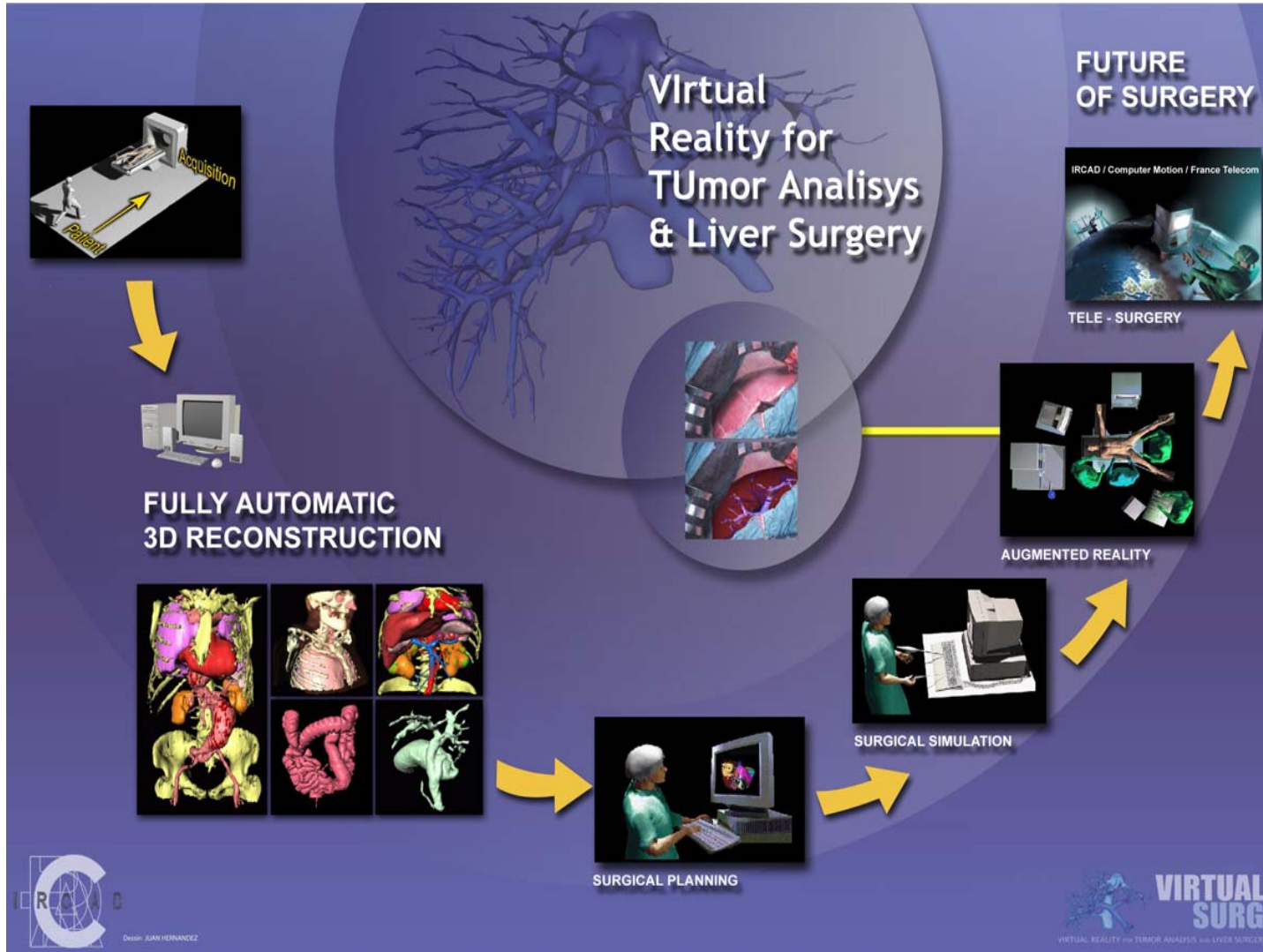
**No FFB / 5DOF**  
***Simendo***  
**~300 €**



**3 DOF FFB**  
***Novint Falcon***  
**100 \$**

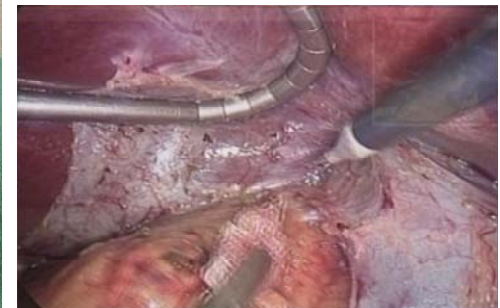
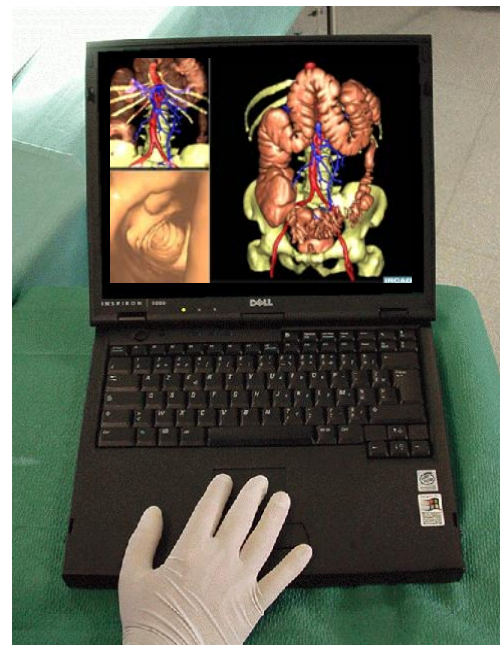


# Intra-operative Use



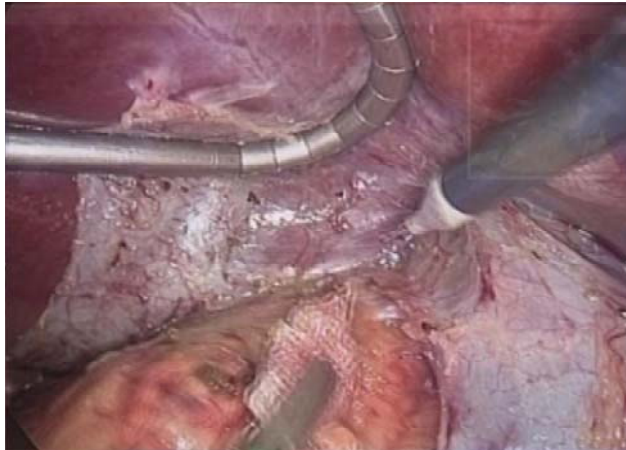
# Surgical planning software

## Open or laparoscopic Surgery



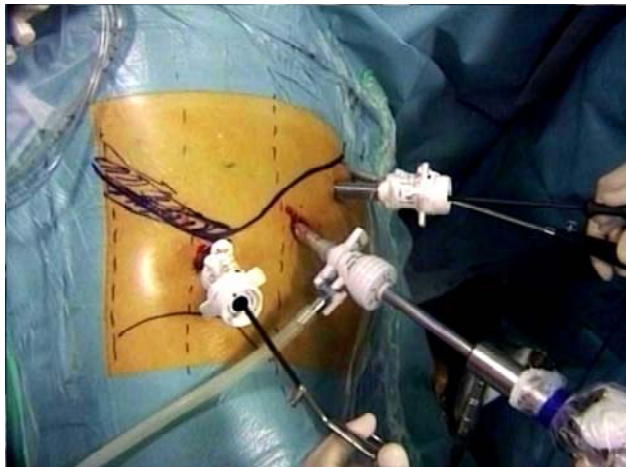
# Forth Step : Intra-operative Use

## Surgical views



**Internal view**

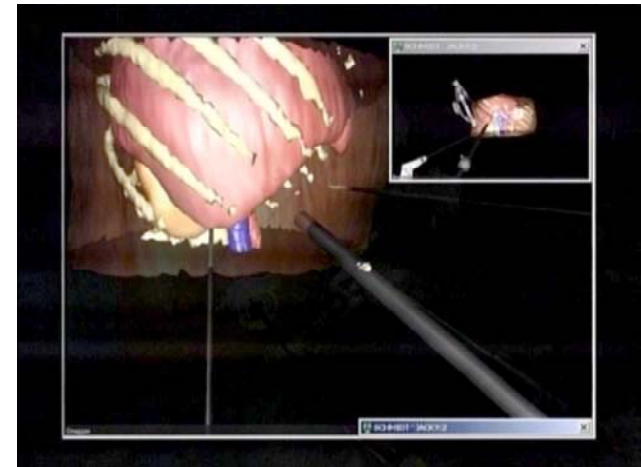
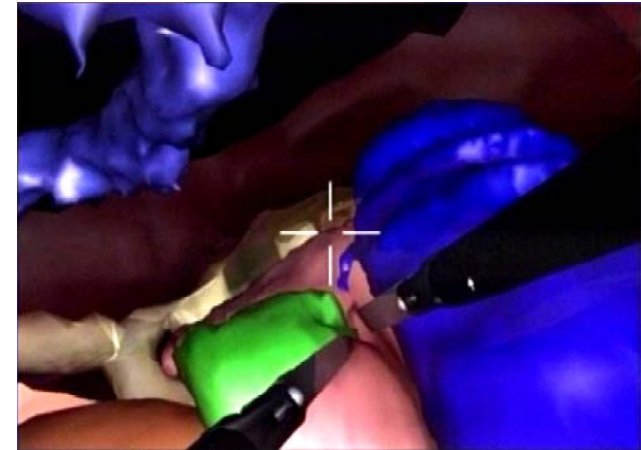
**Real Virtual**



**External view**

**Real Virtual**

## Laptop views



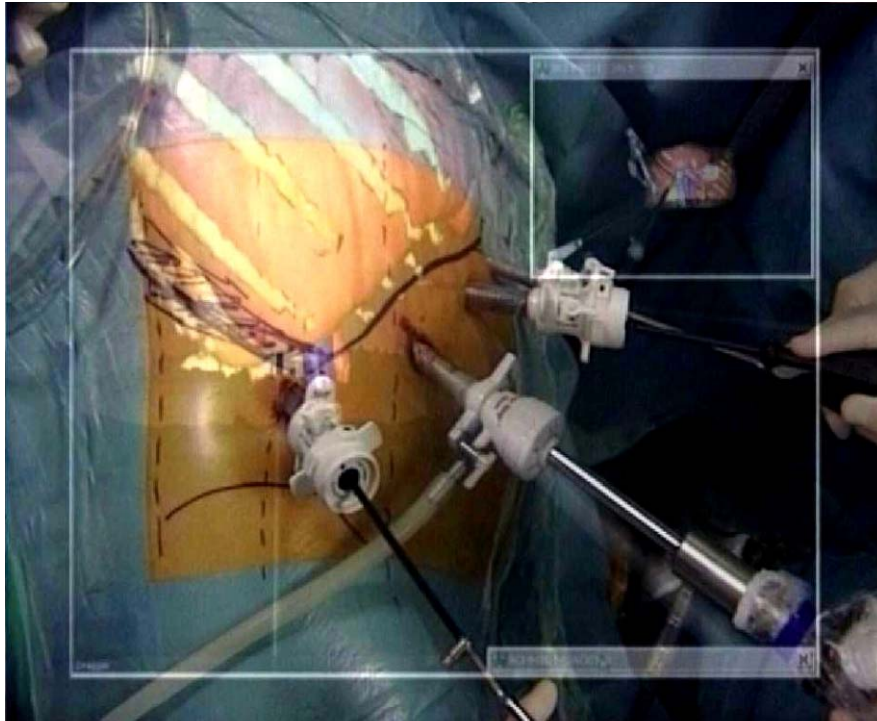


# Forth Step : Intra-operative Use

Optimal use : Fuse real and virtual

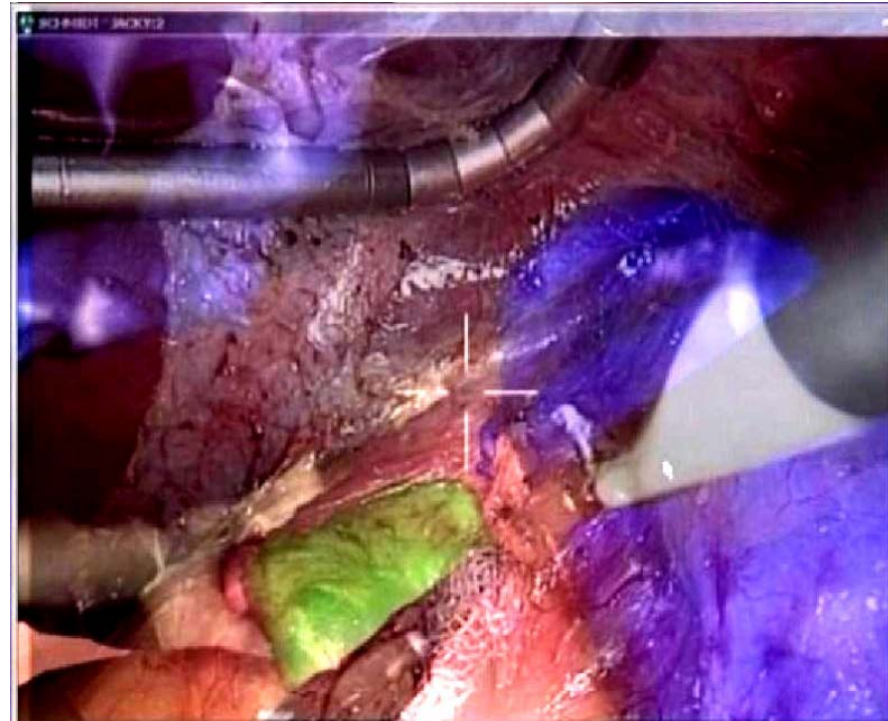
External view

Real + Virtual



Internal view

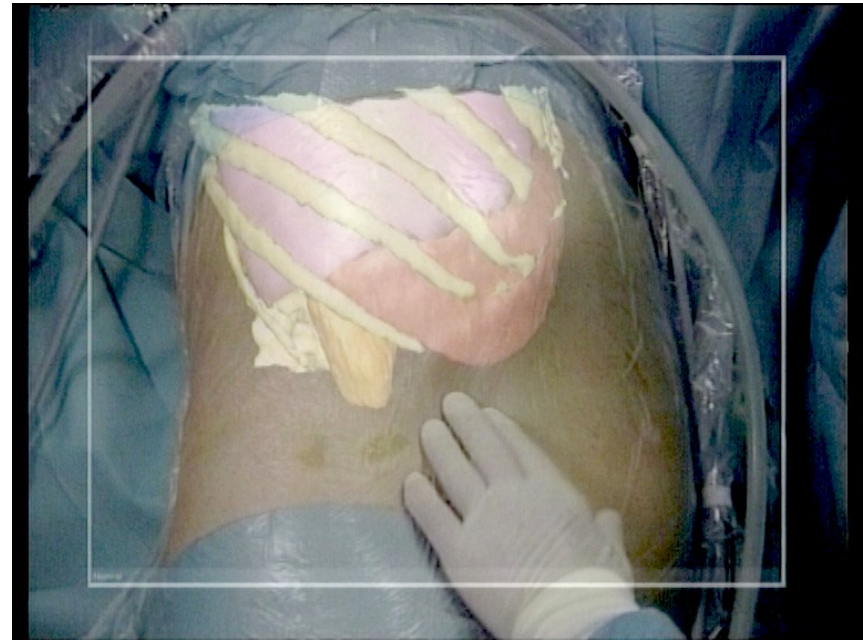
Real + Virtual





# Interactive Augmented reality

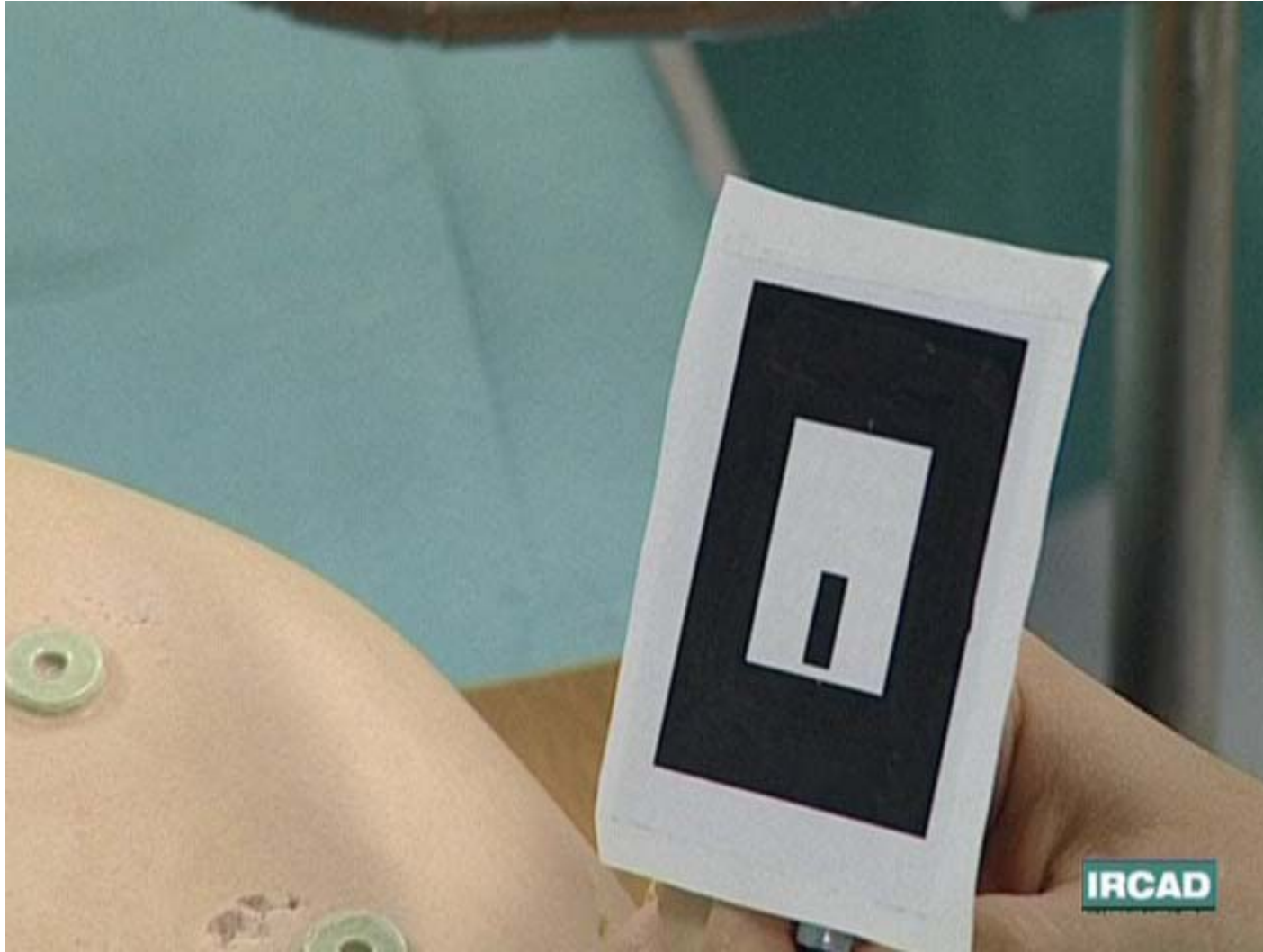
50



*JAMA November 2004*

**ircad**

# Fully Automated Augmented reality <sup>51</sup>



# Limits ...

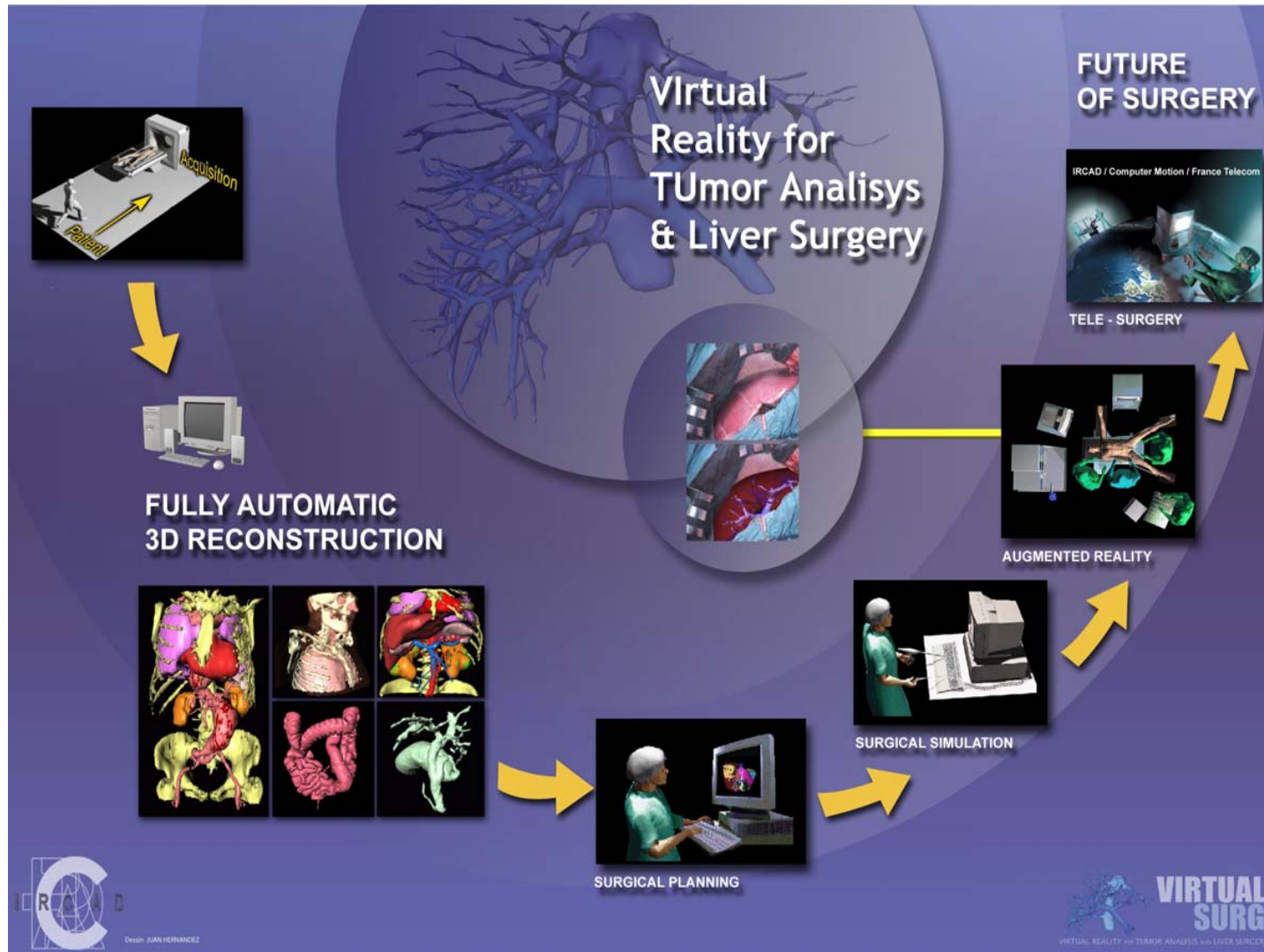
**What about breath or patient movement ?**

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

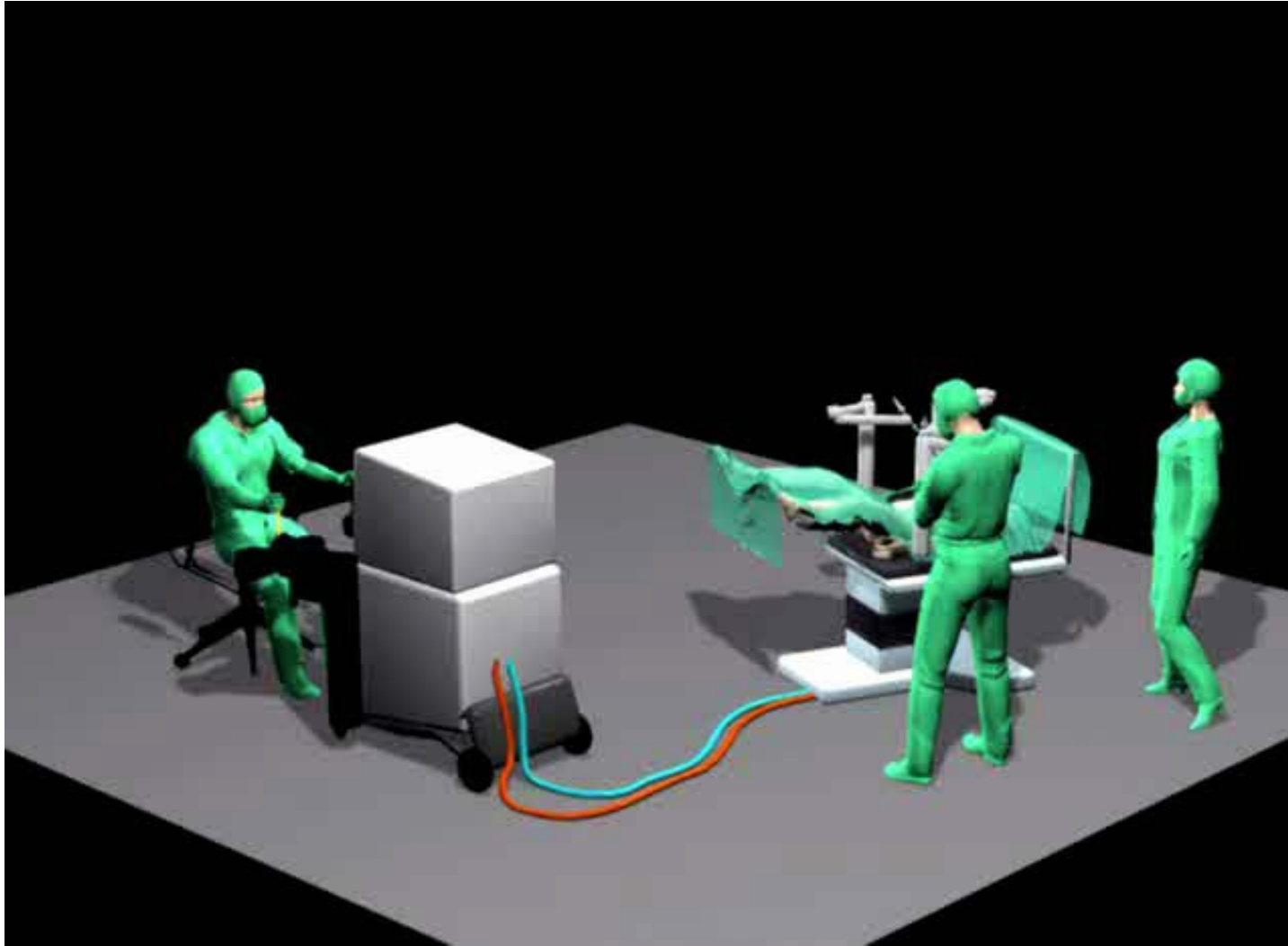
**But : intermediary solutions are possible for limited movements**

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

# Robotics



# Robot : TeleSurgery

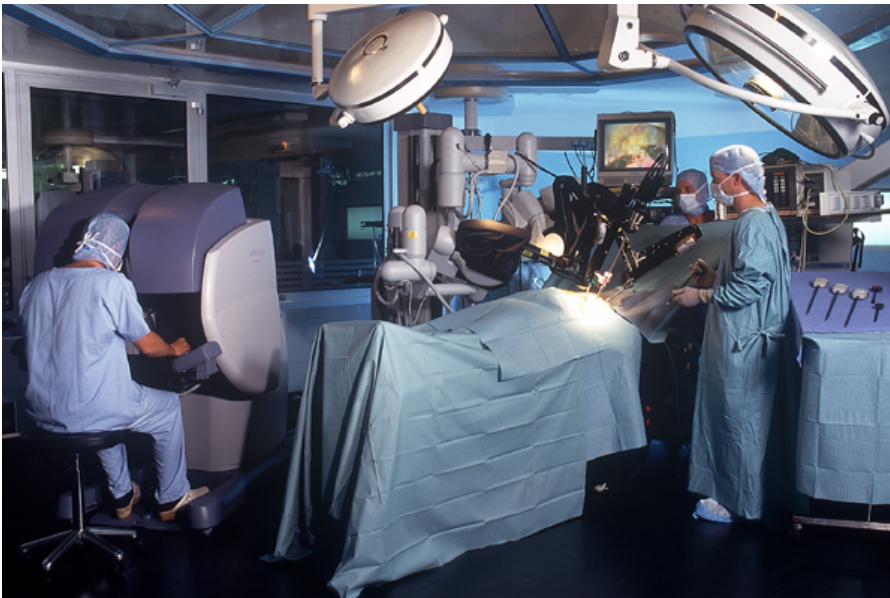




# Robot : TeleSurgery

## 2 Robots, 1 Society : Intuitive Surgical

Da vinci



Zeus



***But new solutions are arising :  
Artemis, Hitachi, 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

# Robotics

## State of the art

- Feasibility 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 7<sup>th</sup> 2001



# A medical revolution ?...



## Transatlantic robot-assisted telesurgery

ATM technology now enables operators to be performed over huge distances.

**brief communications**



Figure 1 Surgeon operating the robotic console in New York to perform the first instance of a robotic procedure.

The introduction of robot-assisted laparoscopic cholecystectomy (gall bladder removal) in 1991, and the subsequent development of the 'da Vinci' robot, have opened up new possibilities for minimally invasive surgery. The ability to perform such operations from a remote location has been the focus of research in the field of telemedicine. The ability to perform such operations from a remote location has been the focus of research in the field of telemedicine. The ability to perform such operations from a remote location has been the focus of research in the field of telemedicine.

network that interconnects applications at host (NTU), which provides a multiuser path to different applications. To monitor and measure its level of quality, the NTU under inserted operating and maintenance packets within user data packets, which were extracted and analysed by the remote NTU receiver. By analysing these packets and comparing the number of packets actually sent to those that were actually received, we determined the number of lost packets. Operation and maintenance tasks revealed that the ATM packet was lost during any surgical procedure. The round-trip delay by ATM transport was 78–80 ms. Adding 70 ms for video coding and adaptation, plus a few milliseconds for data conversion, movements executed by the surgeon in New York were apparent by the 153 ms on his video screen.

We successfully carried out laparoscopic remote robotic cholecystectomy in six pigs. At the operative site in New York, two surgeons carried out the procedure and a third monitored the recording. Two surgeons at the remote site set up the trocar position and were able to inactivate the robot if necessary for safety reasons. Coagulation was coordinated by voice command between the sites. The mean time for cholecystectomy was 45 min (range, 26–78 min). The three surgeons in New York subjectively evaluated, in a blinded manner, the quality of the image, the impact of time lag on performance, the coordination and



Figure 2 Robotic arms at the remote site in Strasbourg.

# Robotic Tele-mentoring



Courtesy of *InTouch Health*

**ircad**

# Robotic Tele-mentoring



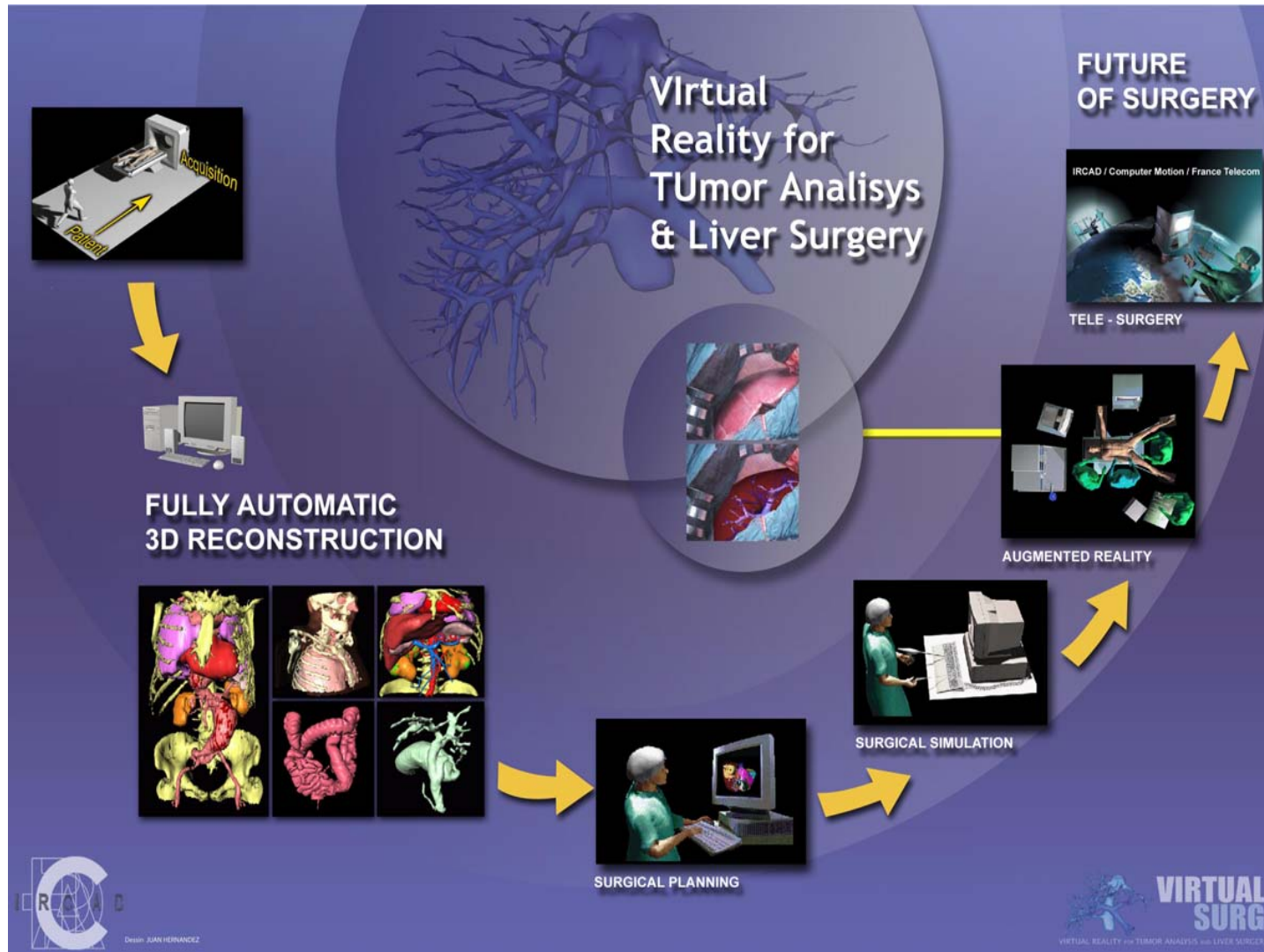
# Tele-mentoring from Pocket PC



Operating room

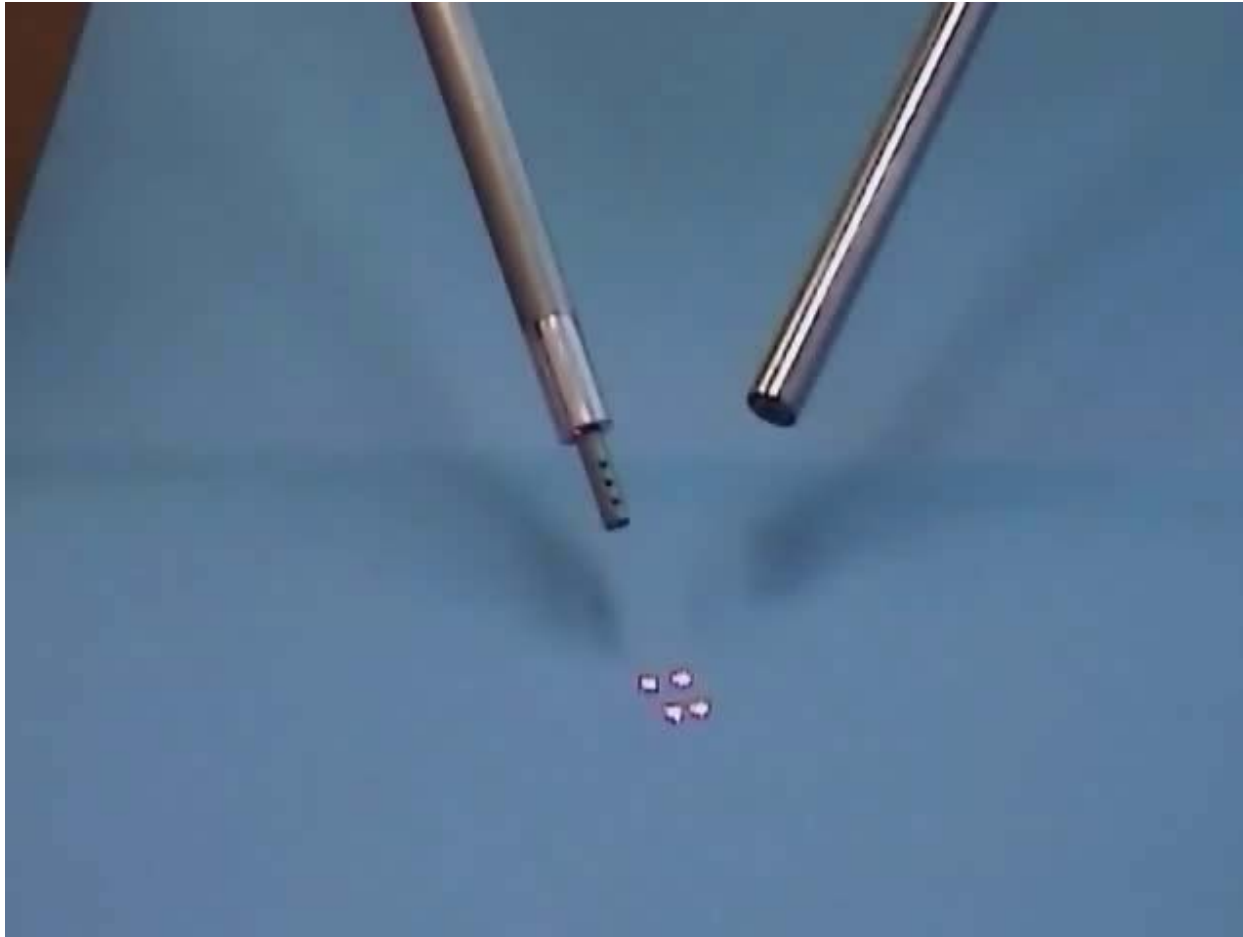


# Robotics Automation



# Visual servoing of Robotics

## Visual Control



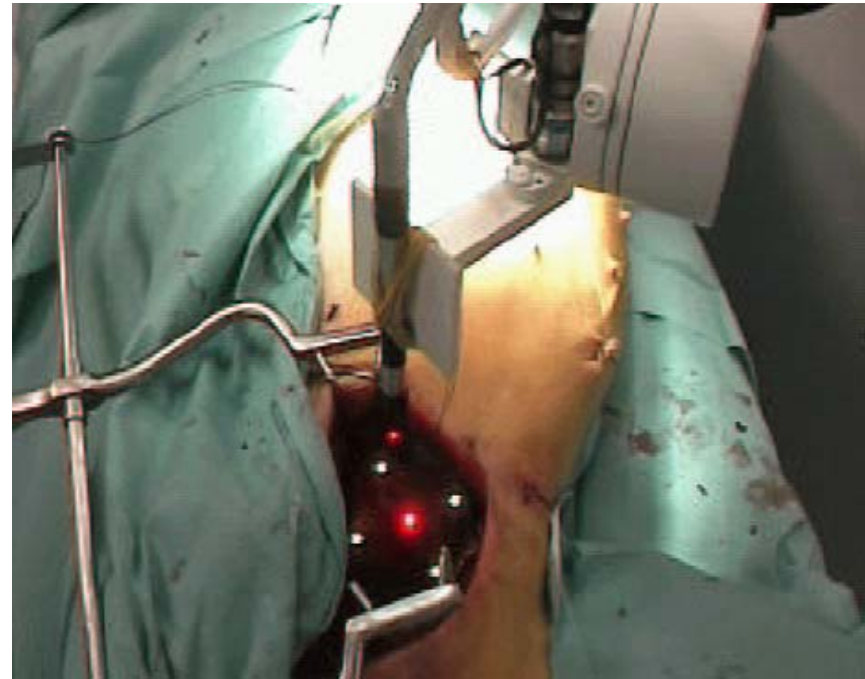
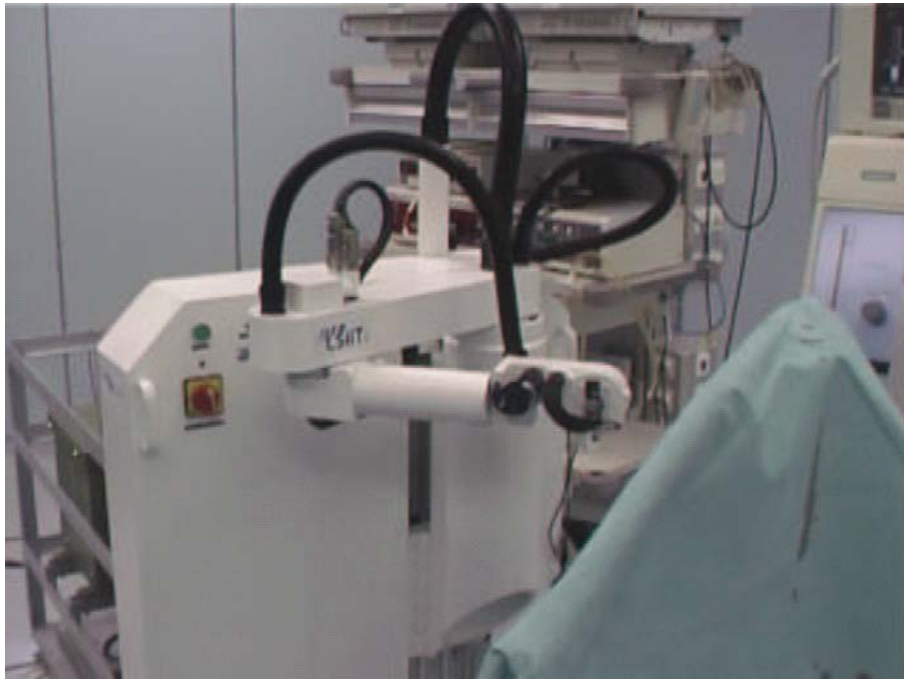
# Visual servoing of Robotics

## Visual Control



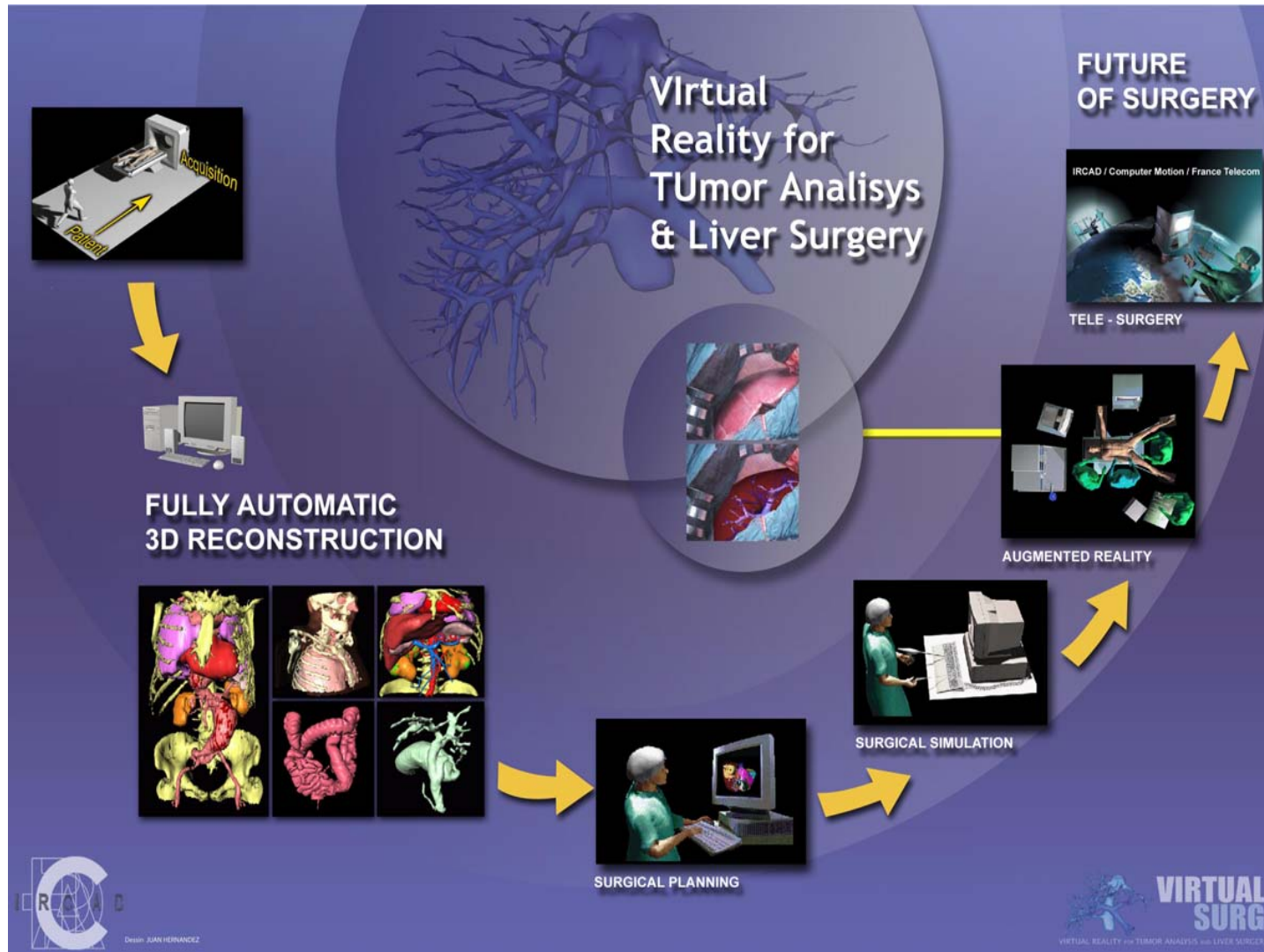
# Visual servoing of Robotics

## Visual Control





# Future of Robotics





# Robotic Tele-mentoring



Courtesy of *InTouch Health*

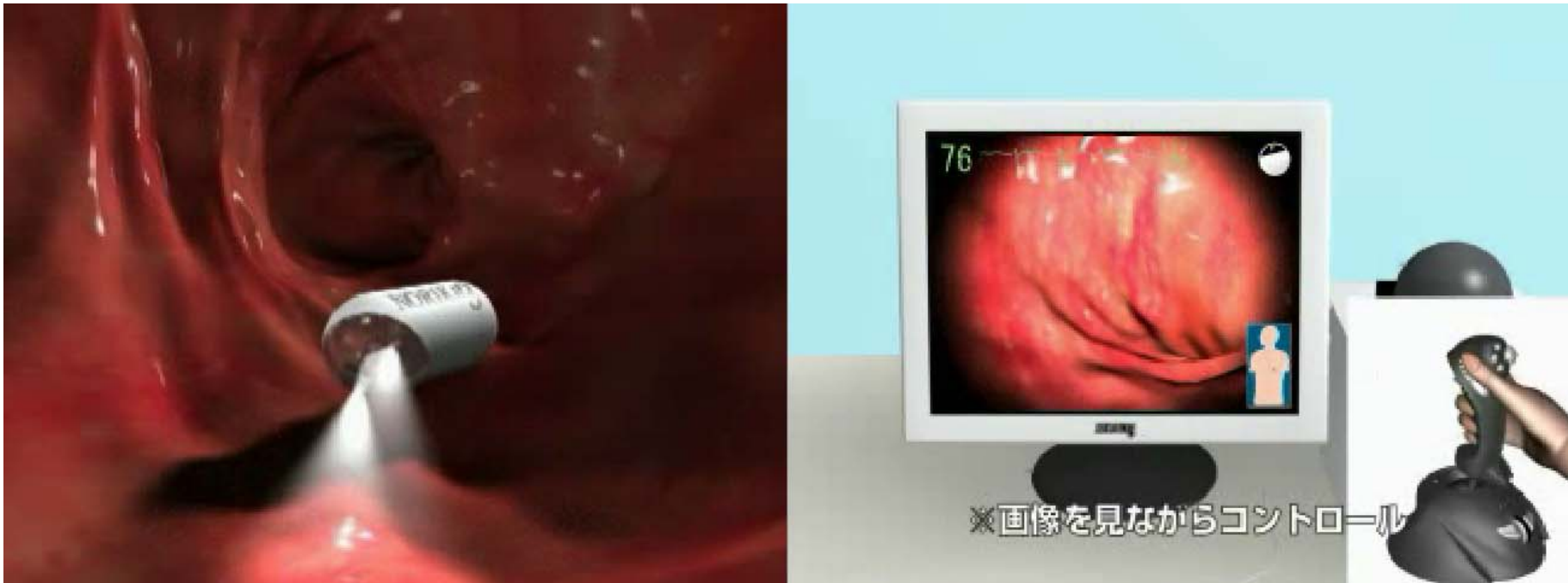
# New Generation : Humanoid ?



*Honda (Japan)*

**ircad**

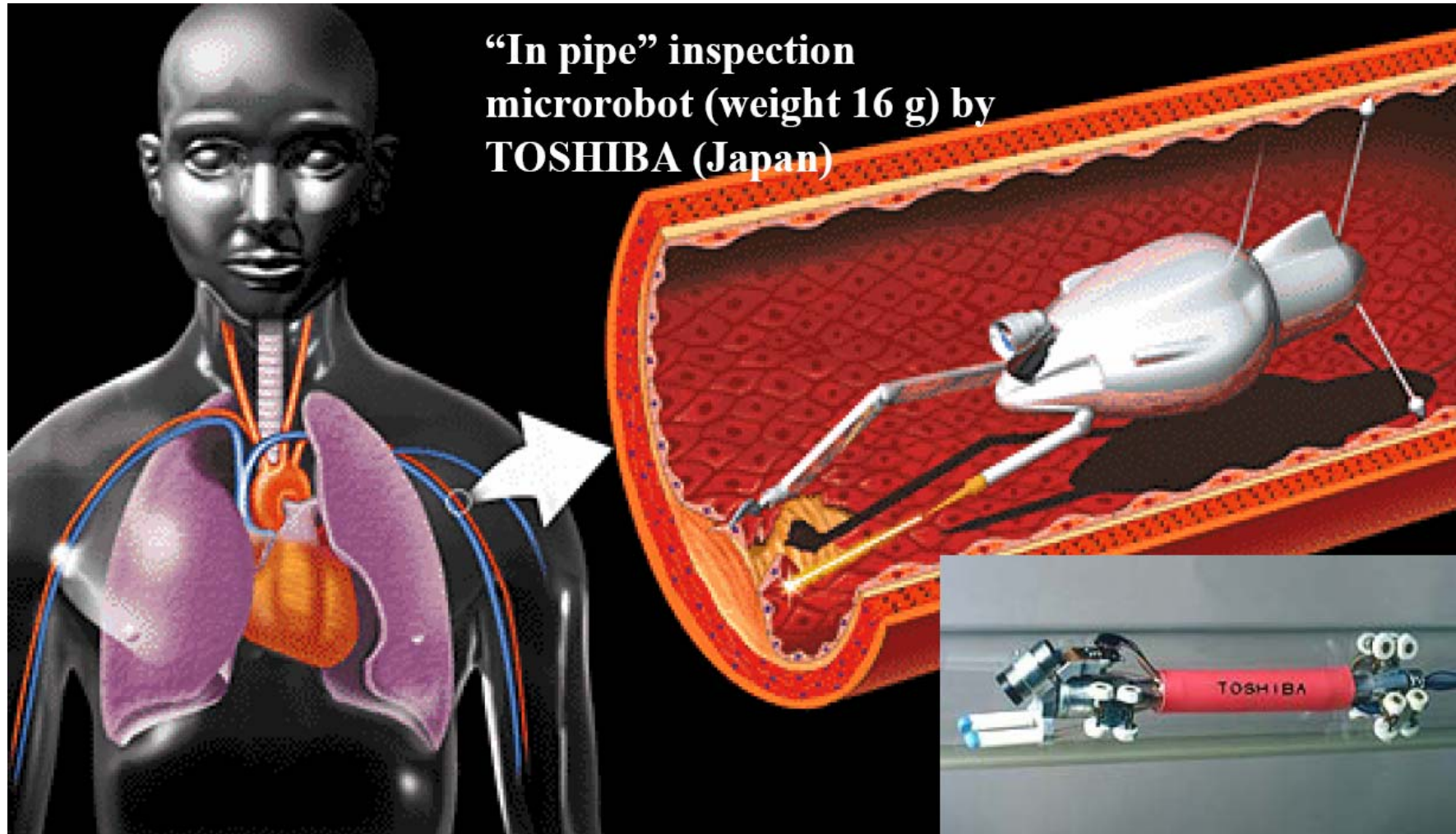
# New Generation : MicroRobot



***Norika (Korea)***

**ircad**

# Next Generation : MicroRobot



***Toshiba (Japan)***



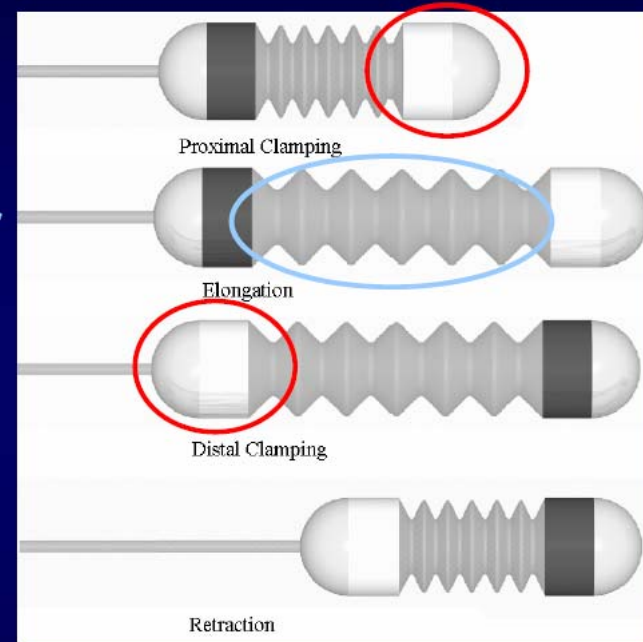
# Next Generation : Biomimetic Robot <sup>74</sup>



Distal clamper

Central elongator

Proximal clamper



**Typical colonoscopy prototype**

Diameter : 24 mm

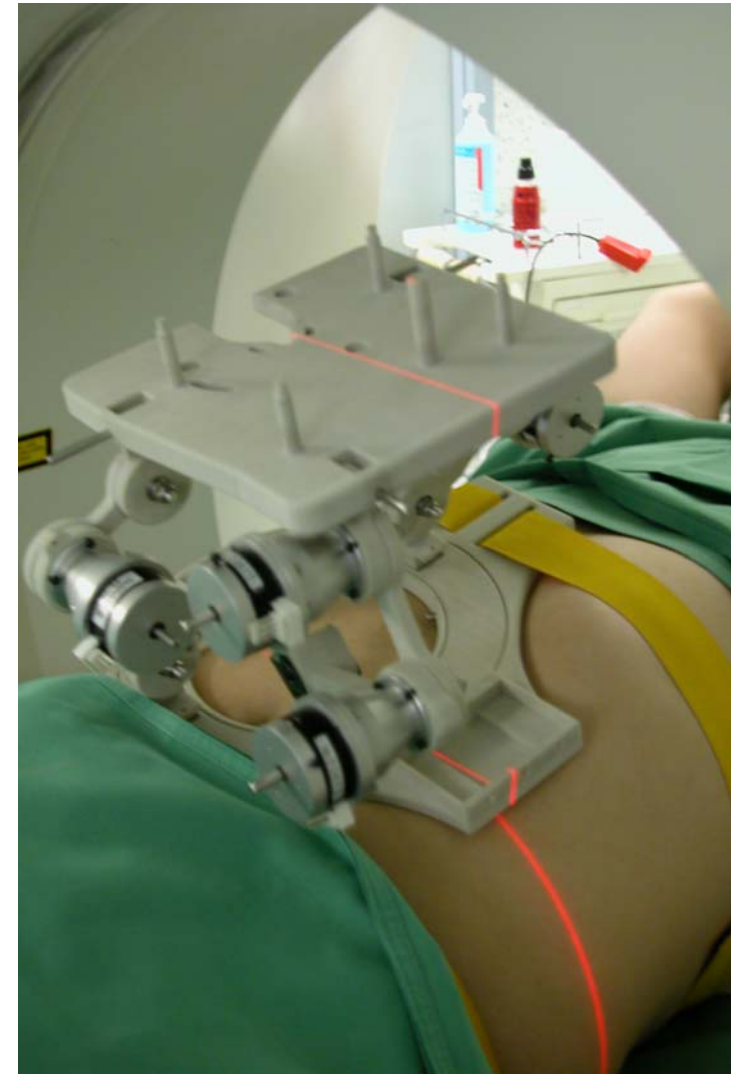
Retracted Length : 115 mm

Elongated Length : 195 mm

Stroke: 80 mm



# New Generation : smallest



## CTBot:

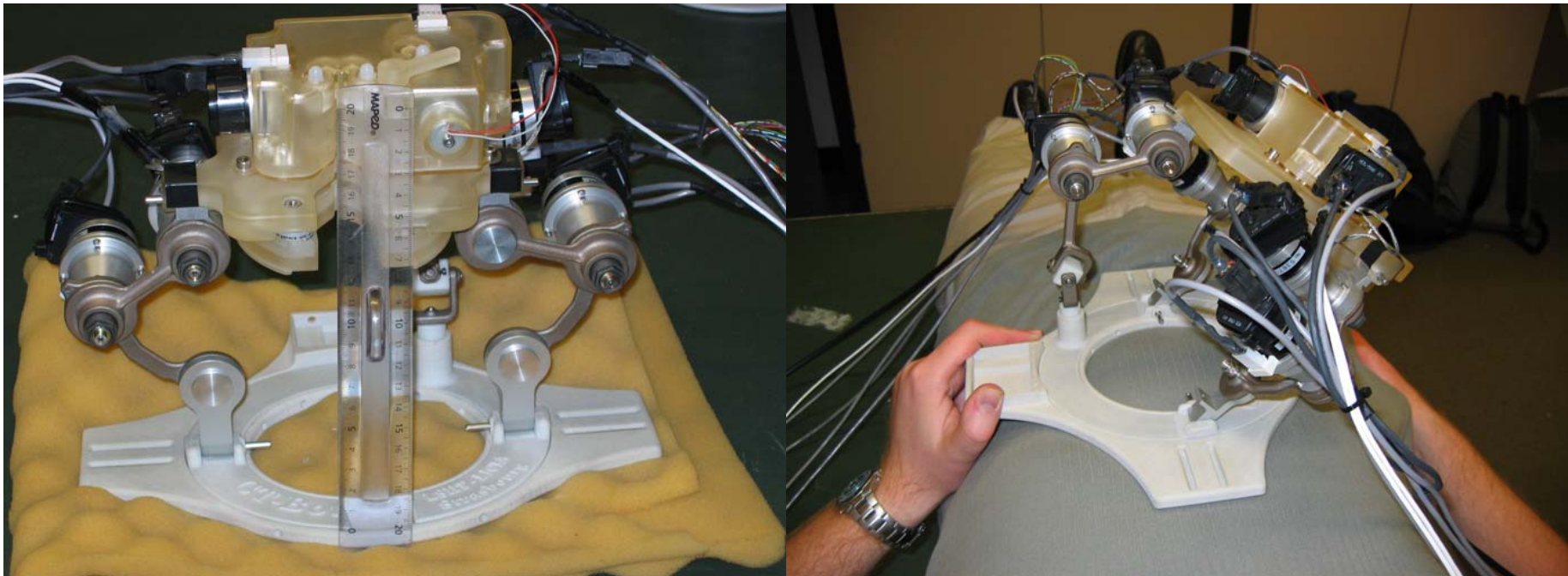
- 7 DOF positioning robot
- Automatic needle placement
- Automatic needle release
- Force sensors

*Percutaneous needle insertion robot*

**ircad**

# New Generation : smallest

**CT-Bot**



*Percutaneous needle insertion robot*

**ircad**

# New Generation : smallest

**CT-Bot** 

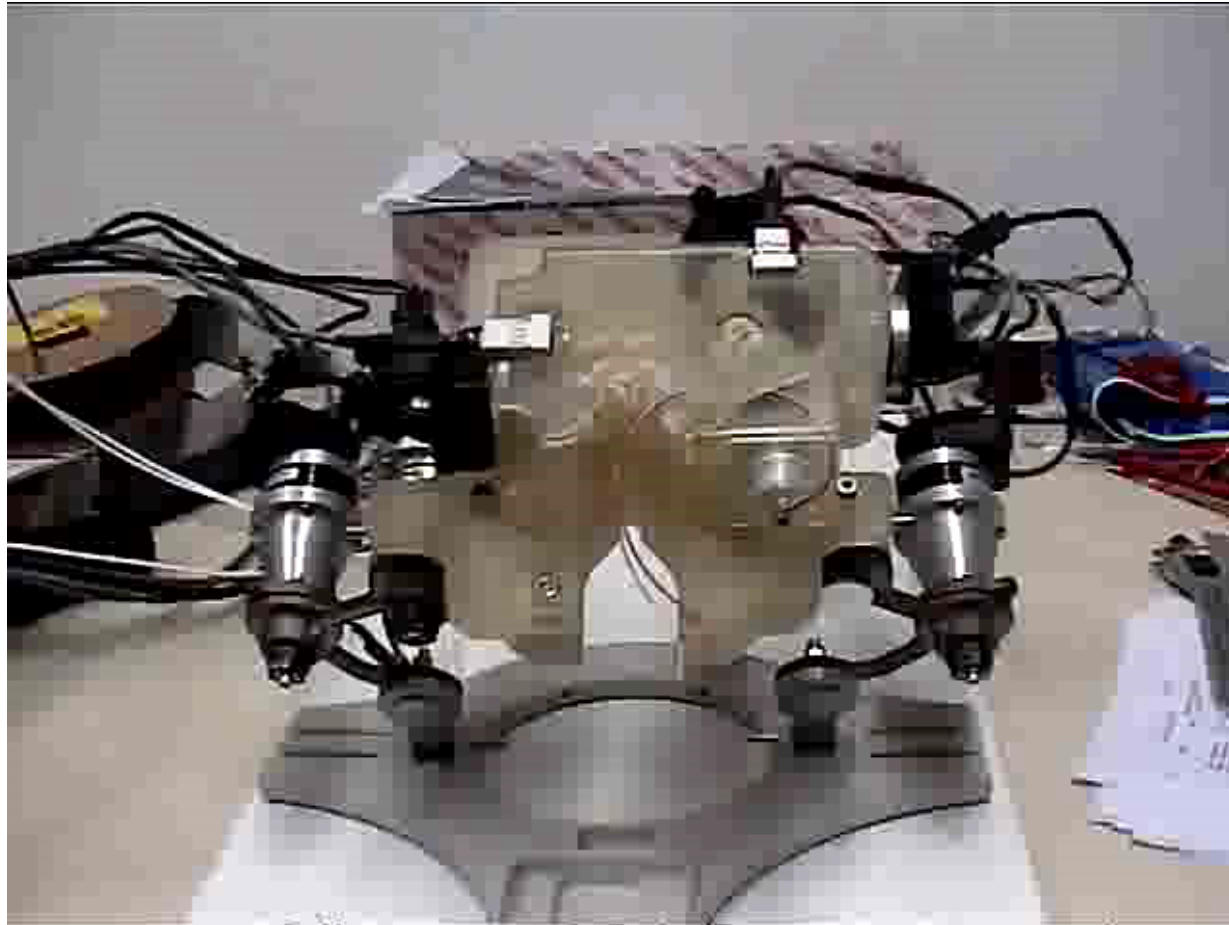


*Percutaneous needle insertion robot*

**ircad**

# New Generation : smallest

**CT-Bot**  ulp  
UNIVERSITE LOUIS PASTEUR  
STRASBOURG

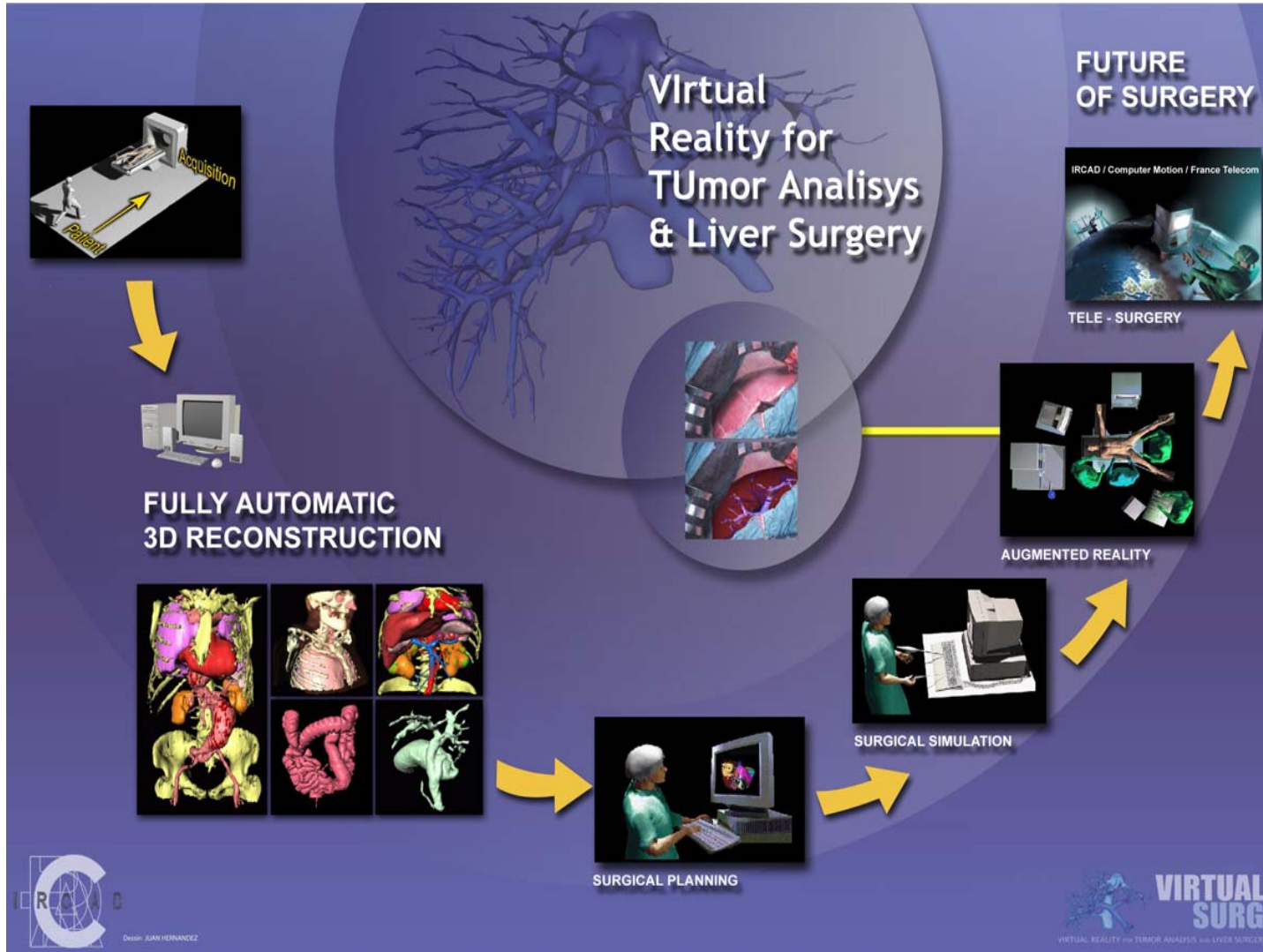


*Percutaneous needle insertion robot*

**ircad**



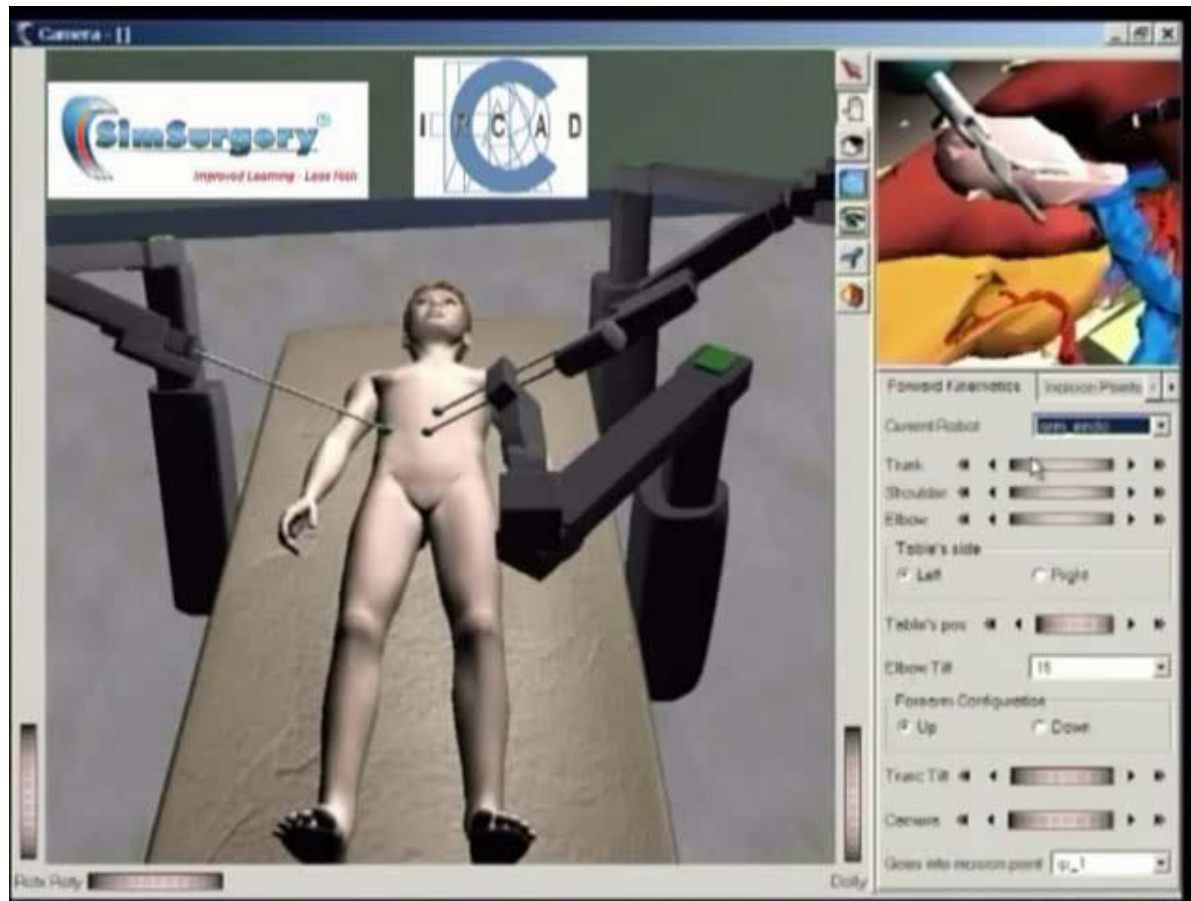
# Conclusion : Future = Automation





# Combine Virtual Reality & Robotics <sup>80</sup>

## Robotic Surgical planning



# Combine Simulation & Robotics

## Robotic Surgical Simulation



# Augmented Reality and Robotics

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# 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 ?**