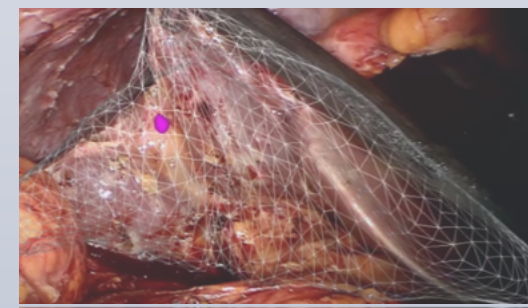
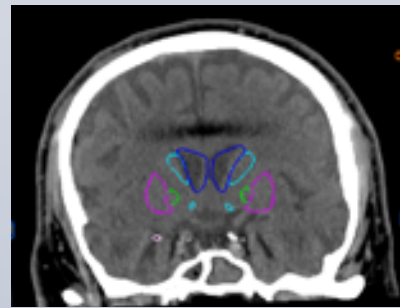
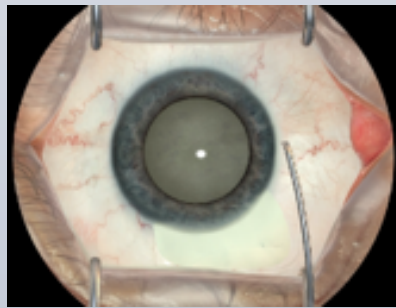


REAL-TIME NUMERICAL SIMULATION

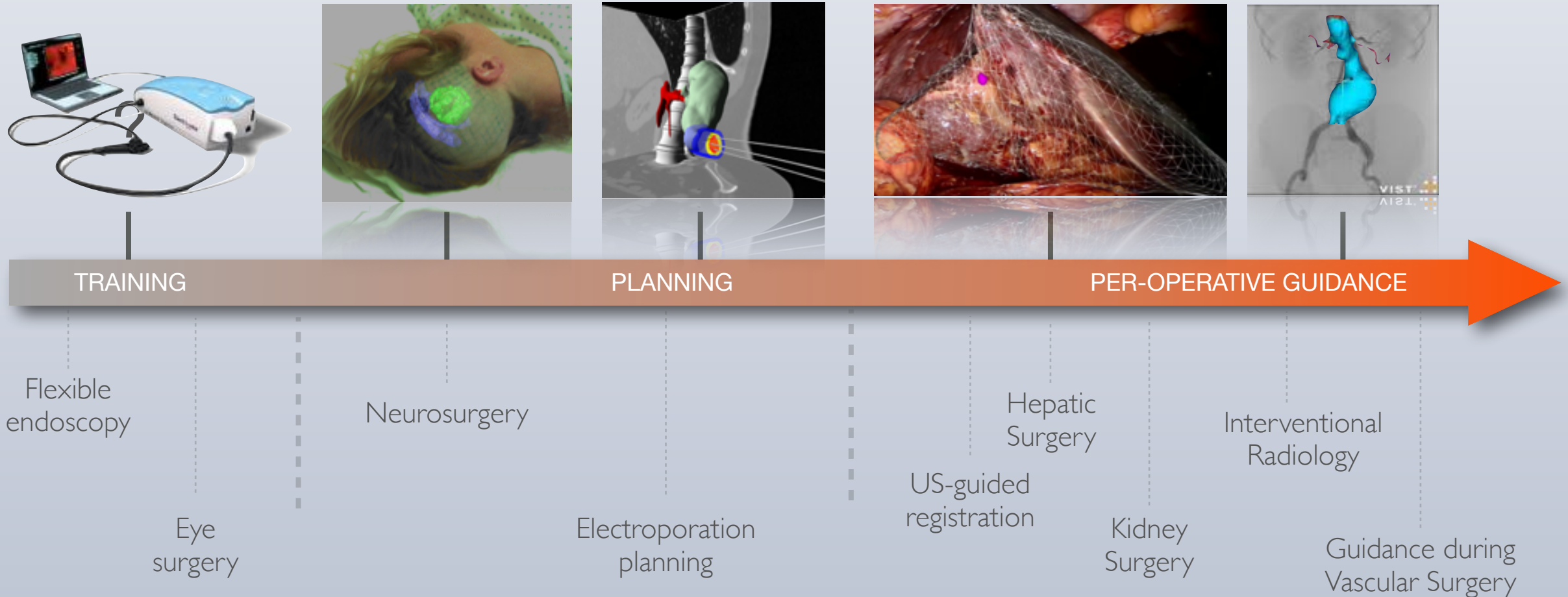
FROM SURGICAL TRAINING TO AUGMENTED REALITY

Stéphane Cotin

Inria



FROM TRAINING TO INTRAOPERATIVE GUIDANCE



FROM TRAINING TO INTRAOPERATIVE GUIDANCE

- **A common objective: reduce surgical errors**
 - Through adapted training, without putting patients at risk
 - With better surgical planning tools
 - By bringing some of these software tools in the operating room
- **Some of the key scientific challenges**
 - Simulate soft tissue deformations due to interactions with instruments
 - Computation must be real-time and patient-specific
 - Register preoperative patient data onto the patient
- **Limitations**
 - Current solutions are often limited yet very expensive
 - Very often, these are ad-hoc solutions, tailored for each problem



NUMERICAL SIMULATION & MEDICINE



1929

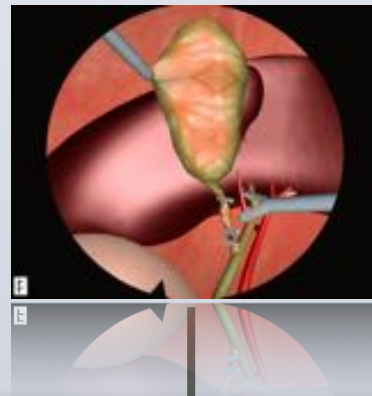
First flight simulator



1999

Simulateur de vol commercial très réaliste

Simulation rendue obligatoire par compagnies d'assurance

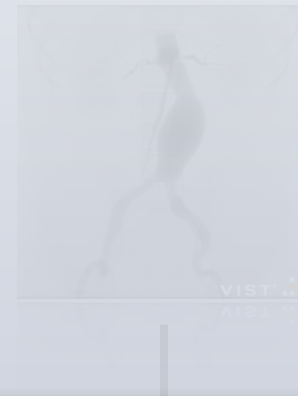


1999

First surgical simulator

Recommandations de la FDA

2000



2002

Simulation de radiologie interventionnelle



2010

Simulation pour le robot DaVinci



NUMERICAL SIMULATION & MEDICINE



1929

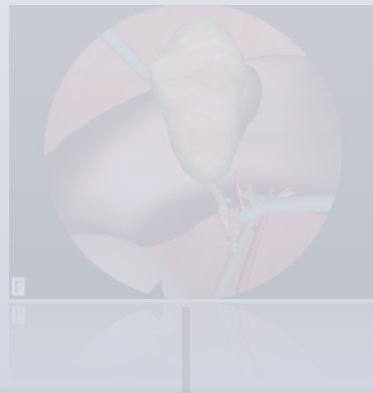
Premier simulateur de vol



1999

Commercial flight simulator

Simulation-based training required by insurance companies

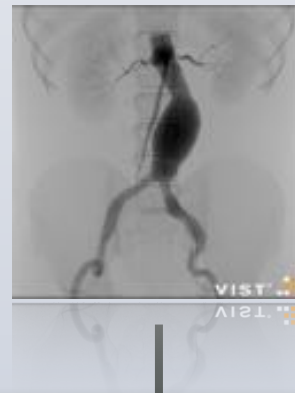


1999

Premier simulateur chirurgical

2000

FDA recommandations



2002

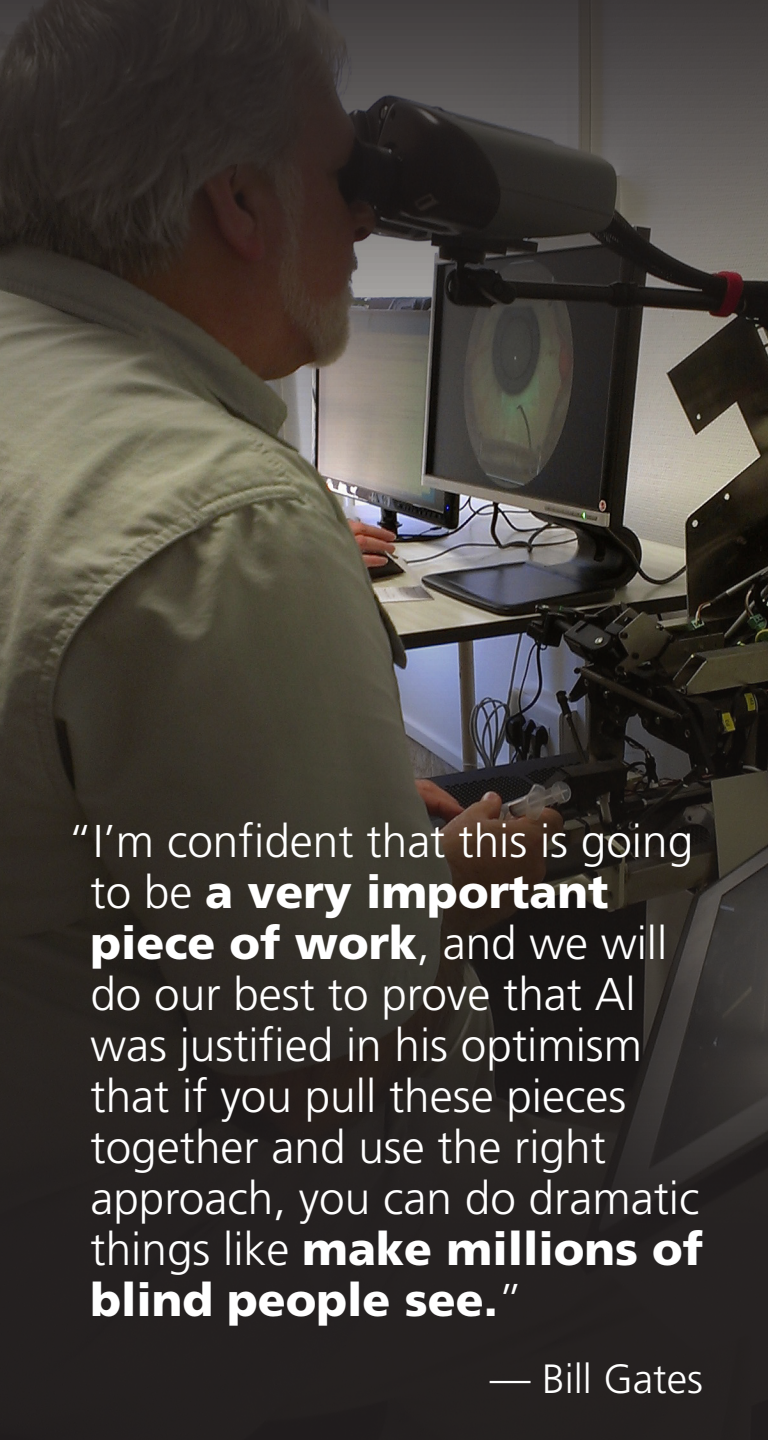
Interventional radiology simulation



2010

DaVinci robot simulator



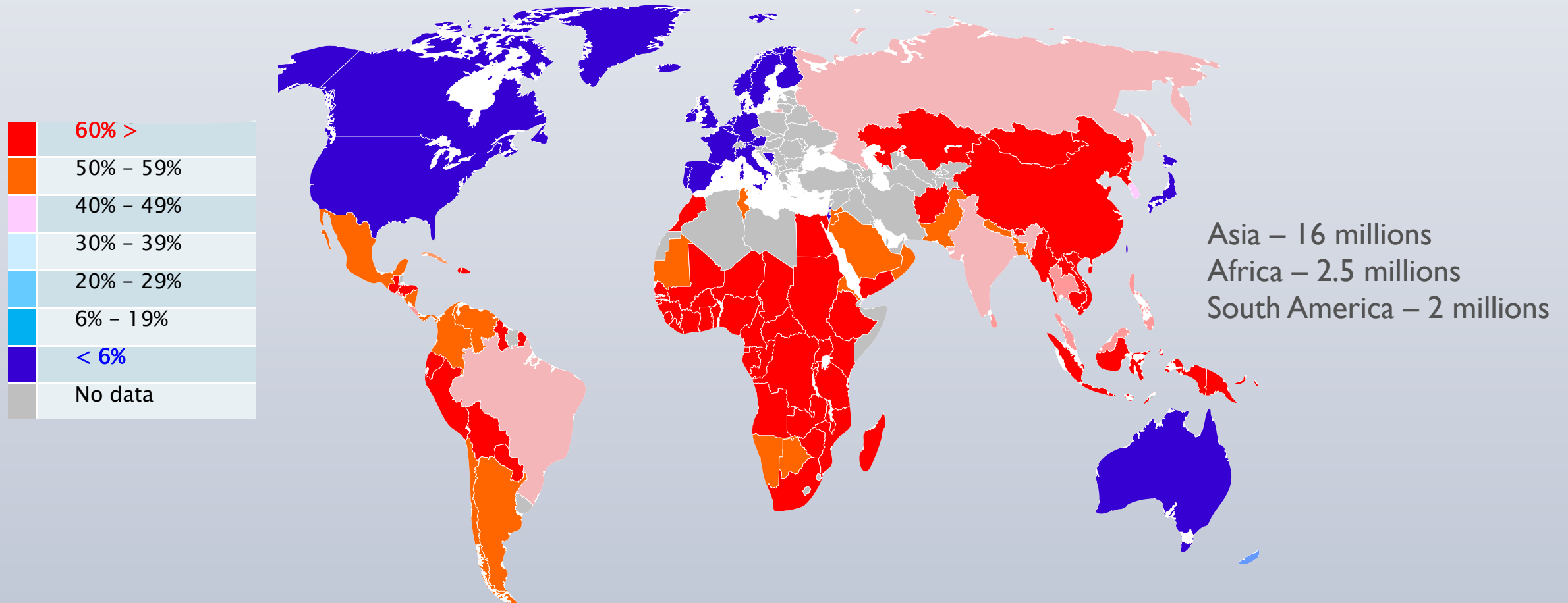


"I'm confident that this is going to be **a very important piece of work**, and we will do our best to prove that AI was justified in his optimism that if you pull these pieces together and use the right approach, you can do dramatic things like **make millions of blind people see.**"

— Bill Gates

THE "HELPMEESEE" PROJECT

A WORLDWIDE PROBLEM...

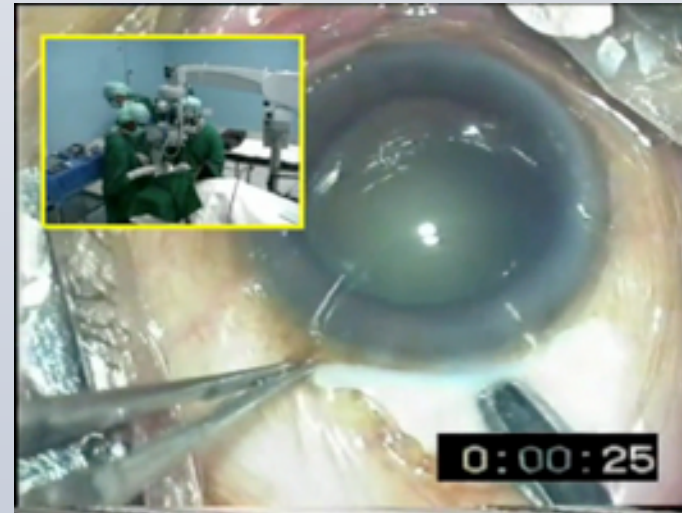


20 million blind children and young adults due to untreated cataracts

... AND AN AMBITIOUS SOLUTION

◎ A new surgical technique called MSICS

- ◎ \$35 and 10 min per surgery
- ◎ Compared to \$5,000 for the conventional approach (phacoemulsification)



◎ But too few surgeons trained at this technique

- ◎ About 150 en 2017 mais 30,000 are needed to treat the 20 millions patients
- ◎ How to train them, efficiently and quickly?

SPEEDUP TRAINING USING REAL-TIME SIMULATION

40 Million blind people worldwide

20 Million blind from cataracts

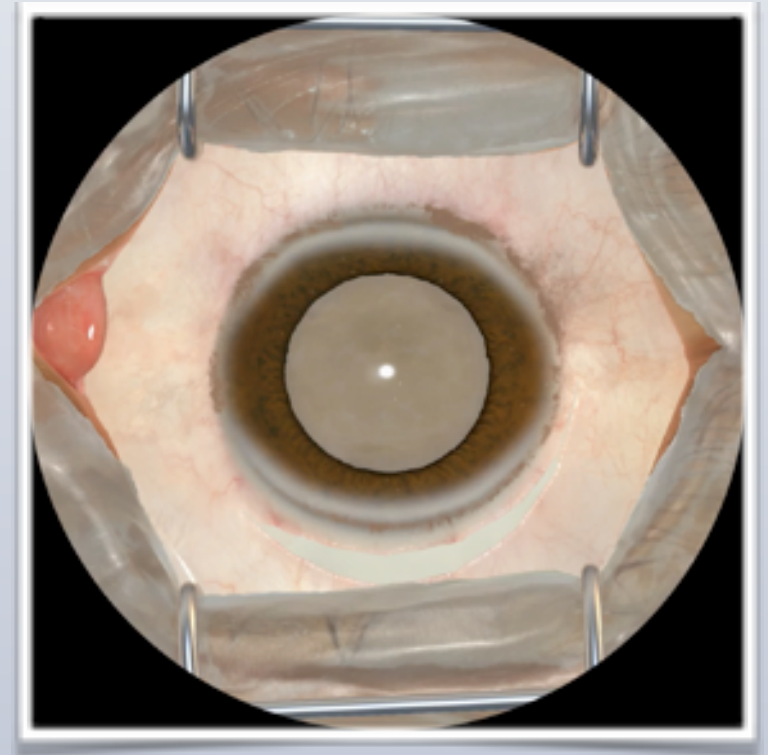
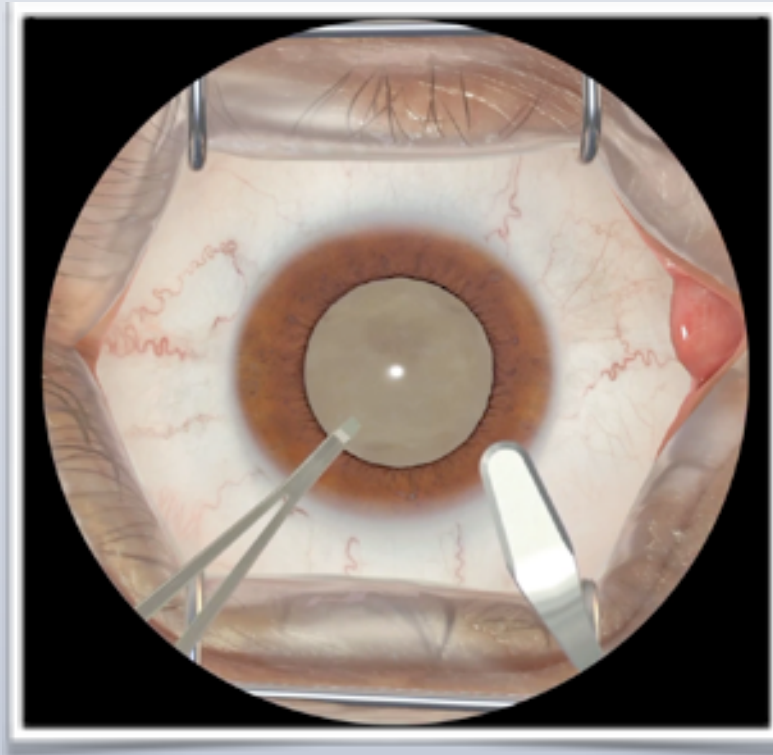
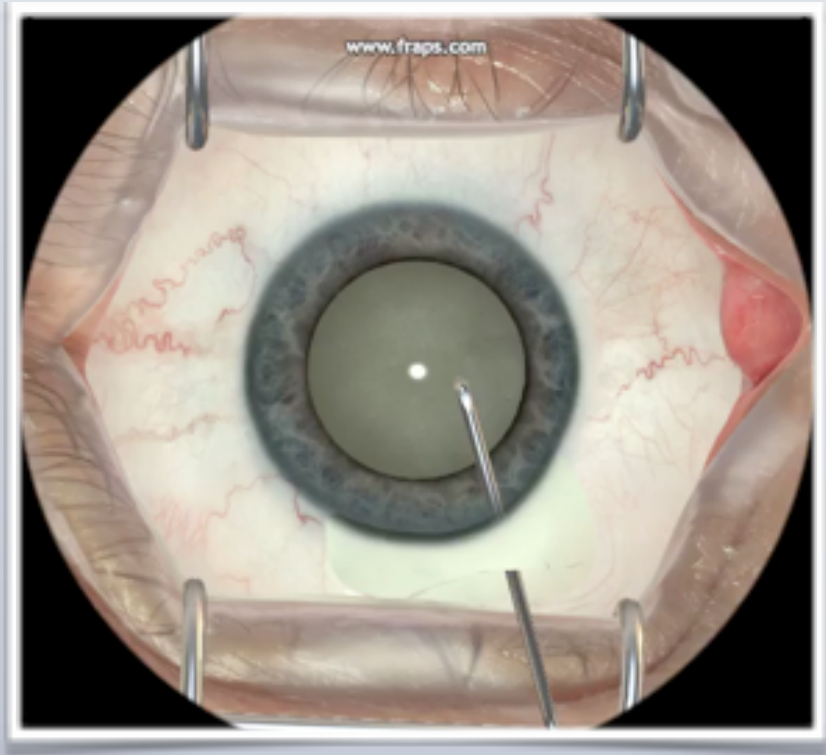
30 Thousand new surgeons needed by 2030

*\$35 to cure 1 adult
\$300 to cure 1 child
Will you help?*

HelpMeSee
Helping the blind see.

- Train 30,000 eye surgeons using numerical simulation
- To meet this goal, simulators will need to
 - Require little maintenance
 - Be very realistic
 - Account for complications et anatomical variations
 - Be available in many training centers
- A new approach to surgical training
 - Normalized surgery
 - 200+ training sessions on simulator
 - 20 supervised interventions on patient

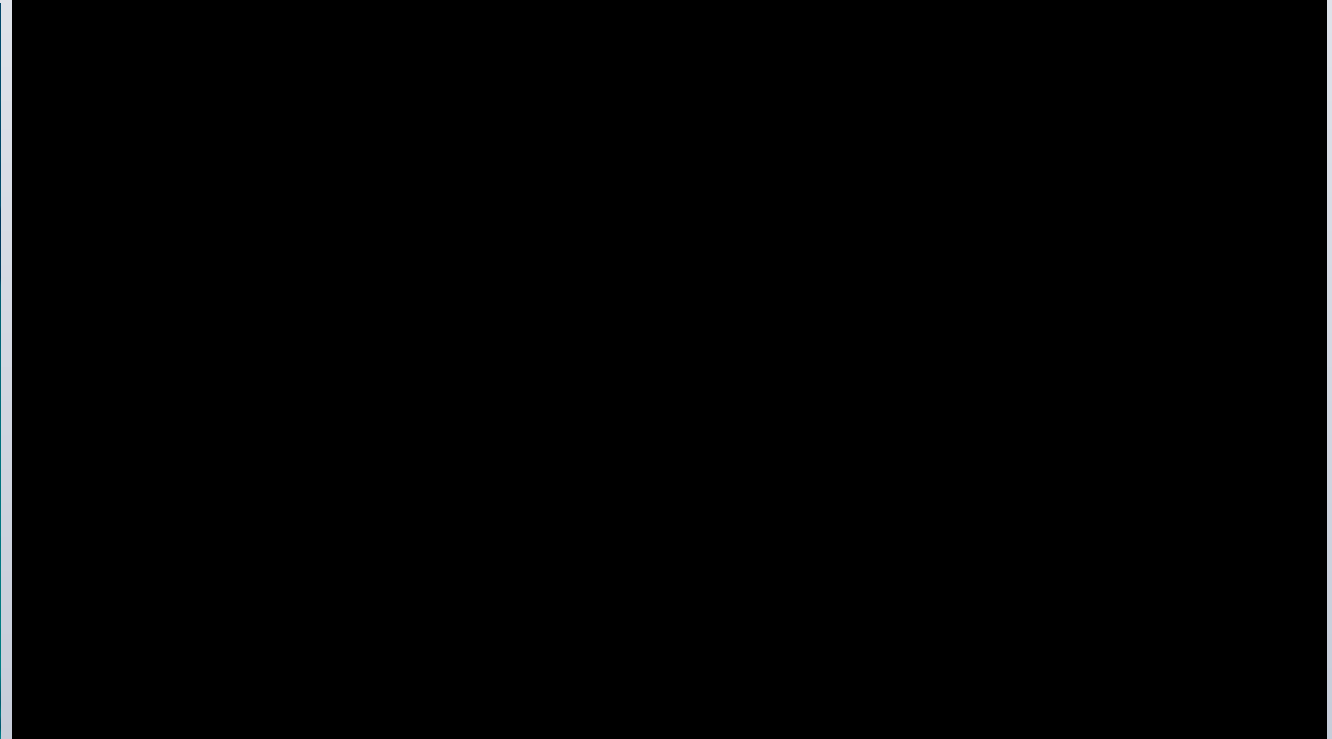
INTERACTIONS – A KEY ELEMENT OF SURGICAL TRAINING



DEVELOPMENT OF A “COMMERCIAL”VERSION



Haptic interface of the MSICS training system



Simulation-based training at HelpMeSee



TOWARDS SURGICAL GUIDANCE

FROM TRAINING TO SURGICAL GUIDANCE

◎ A natural continuum

- ◎ Similar underlying models are needed for training and preoperative guidance
- ◎ It represents a continuity in our research
- ◎ But also a continuity in the use of technology in medicine

◎ But additional challenges need to be solved

- ◎ Need for more complex simulations
- ◎ The simulations still need to be real-time
- ◎ They also need to be personalized

◎ Surgical guidance offers a greater potential

- ◎ Augmented reality during surgery
- ◎ Robotic control in complex environments



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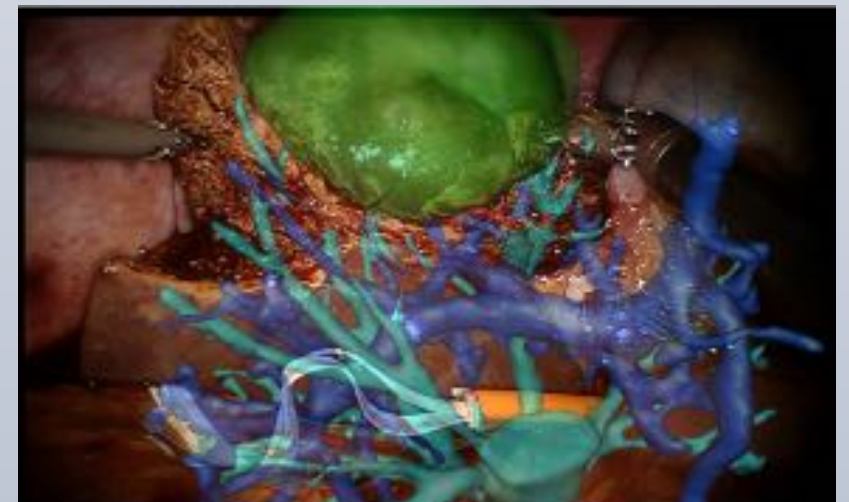
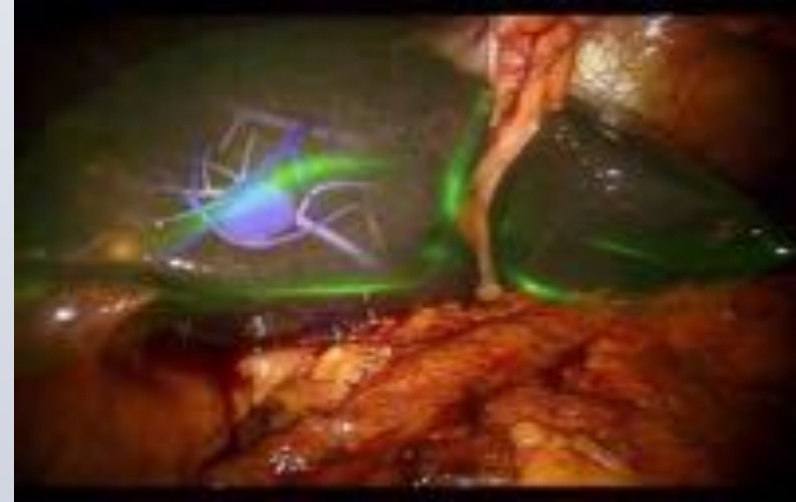
AUGMENTED REALITY IN SURGERY

- **Objective:** visualize anatomical structures normally hidden during surgery to allow for safer, more accurate surgery
- **Challenges:** register preoperative data (i.e. 3D anatomy) in real-time, onto the patient at the time of surgery. Handle deformations and tissue cutting
- **Applications:** orthopedics, neurosurgery, liver surgery, and other abdominal interventions
- **Limitations:** requires either expensive equipment or complex software solutions



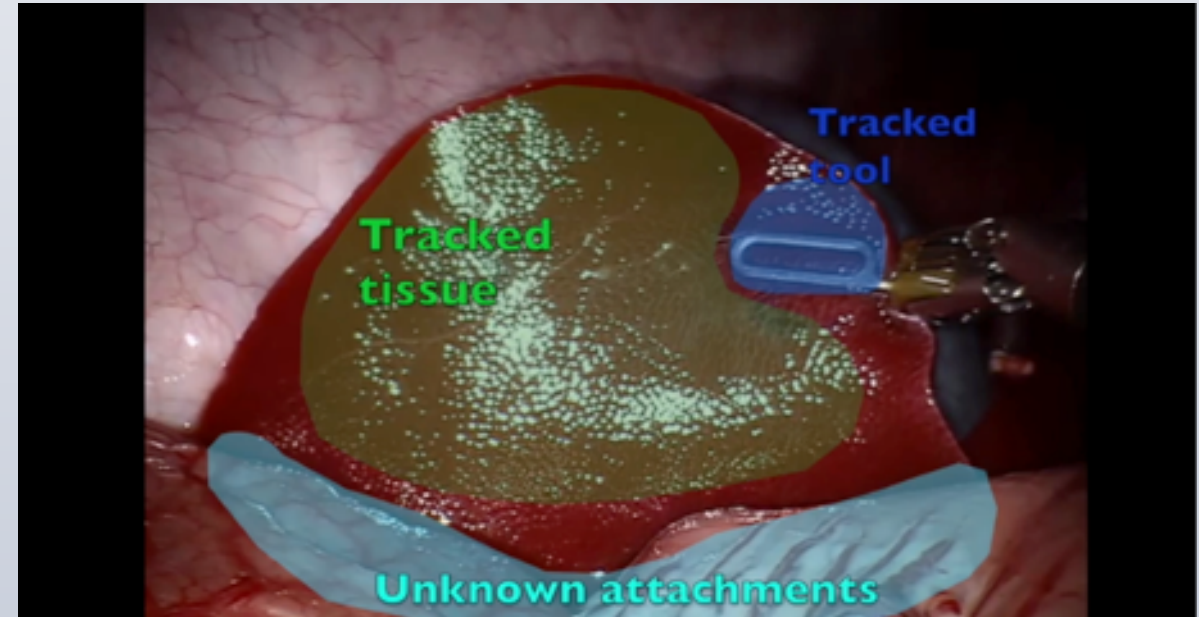
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PERSONALIZED NUMERICAL SIMULATIONS

- ◎ A patient-specific anatomy is not enough
 - ◎ We need to integrate other data / parameters
 - ◎ In particular soft tissue elasticity
 - ◎ But also heat diffusion coefficients, tissue conductance, ligaments, etc..

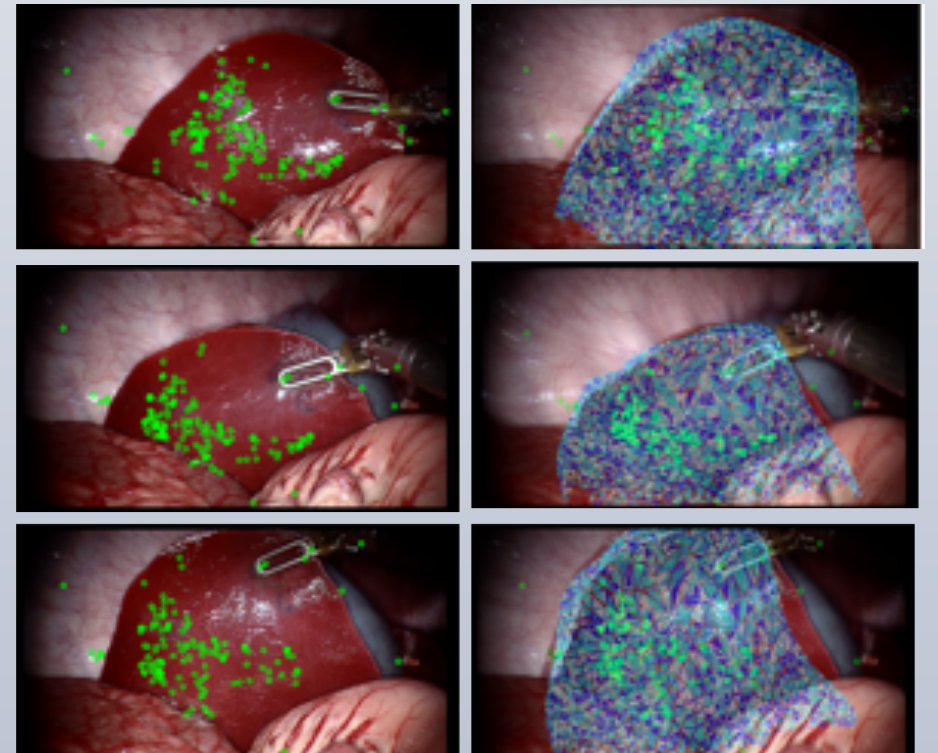


- ◎ Medical imaging makes it possible to measure some of these parameters
 - ◎ Such as elastography
 - ◎ But other parameters need to be estimated from observations and a model: data assimilation

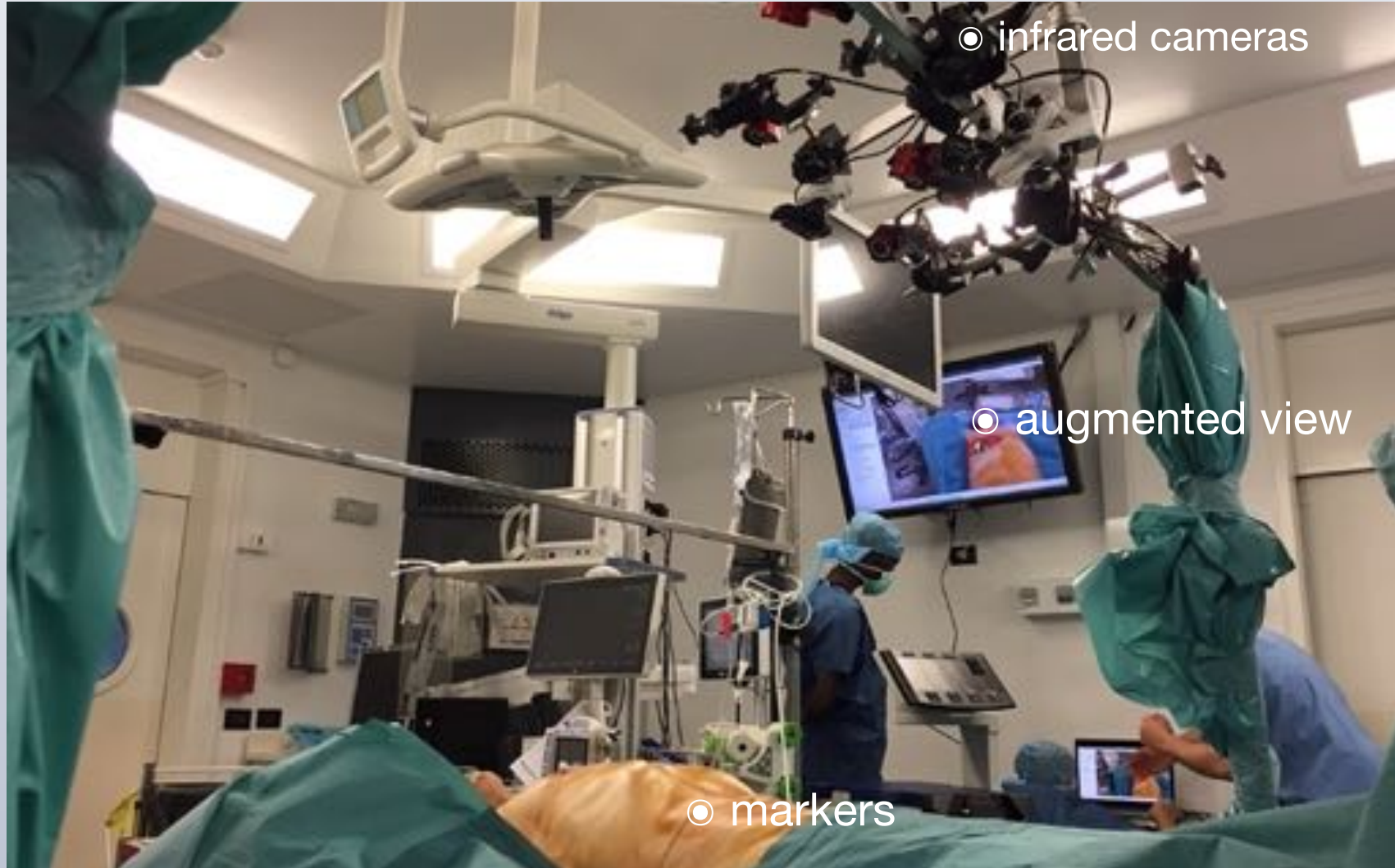
AUGMENTED REALITY DURING LIVER SURGERY

**Image-guided Simulation for
Augmented Reality**
during Hepatic Surgery

Inria



AUGMENTED REALITY DURING LIVER SURGERY



(June 2018)

AUGMENTED REALITY DURING LIVER SURGERY

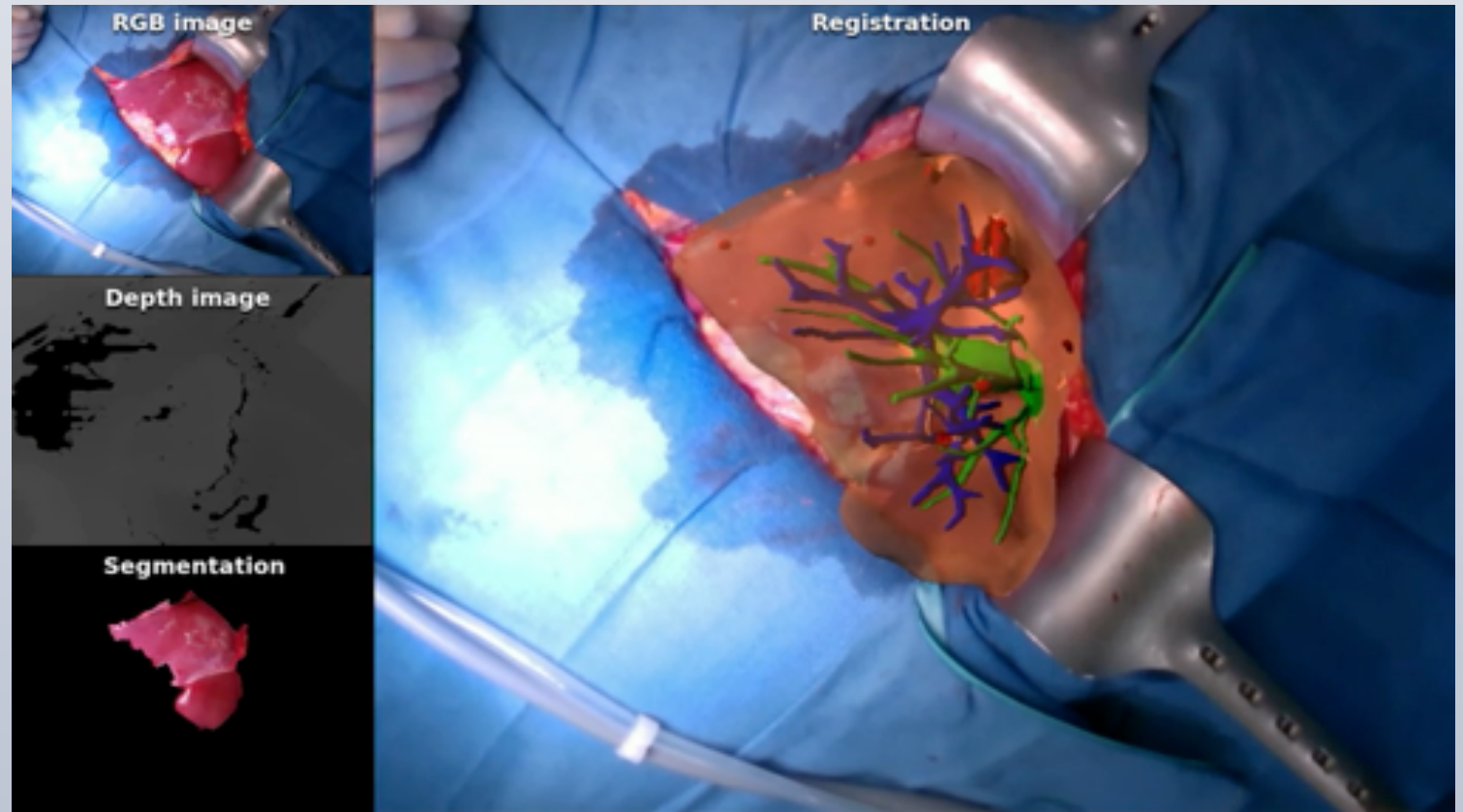


© RGBD camera

© Antoine

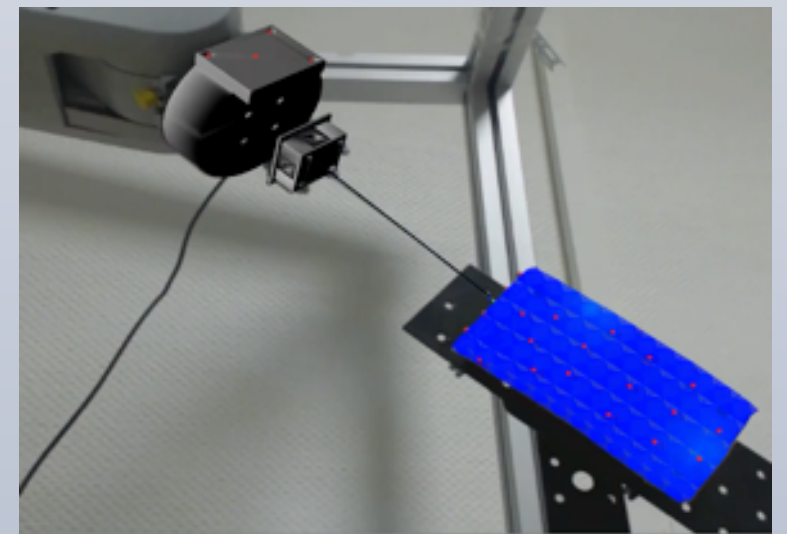
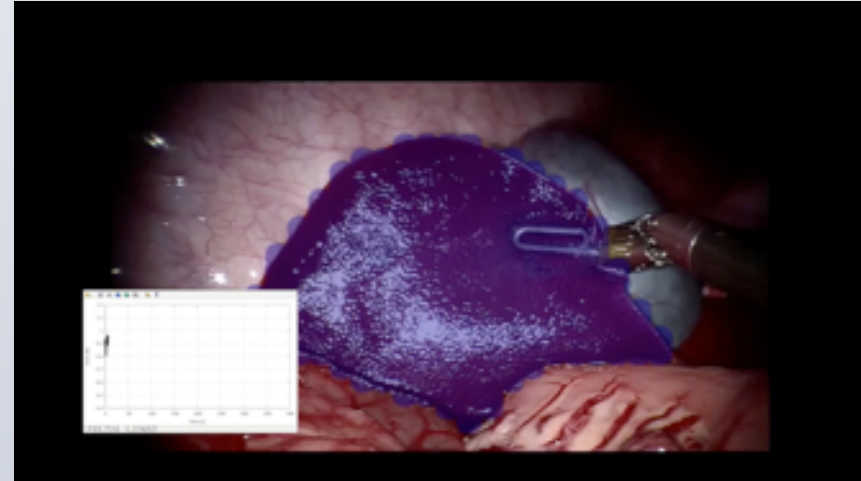
Markerless approach (May 2019)

AUGMENTED REALITY DURING LIVER SURGERY



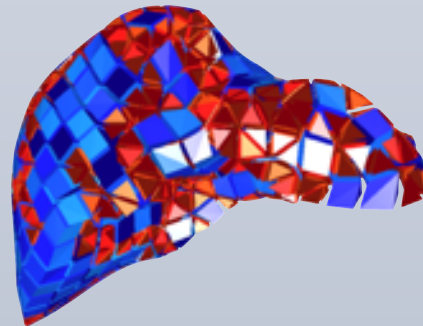
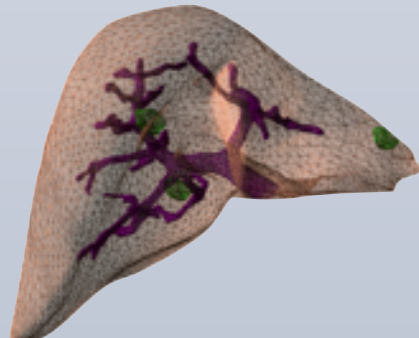
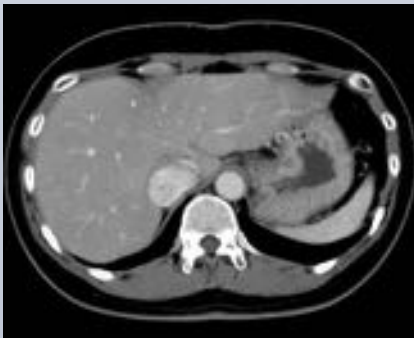
APPLICATION TO SURGICAL ROBOTICS

- Real-time simulation of soft tissue and their interaction with medical devices make it possible to control robotic systems
- Two current applications
- **Force estimation and visualization**
- **Flexible needle insertion under breathing**



A DIGITAL TWIN FOR SURGERY ?

- From a medical image to a digital twin
 - Our next step is to automatize the generation process
 - ... and build a digital twin of the liver for instance, that could be used for Surgical training, surgical planning and interventional guidance
 - We are currently working on the use of AI to link data and models





MERCI DE VOTRE ATTENTION

Et un grand merci à

Christoph Paulus
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