Computer-Aided Surgery of the Uterus by Augmenting the Live Laparoscopy Stream with Preoperative MRI Data
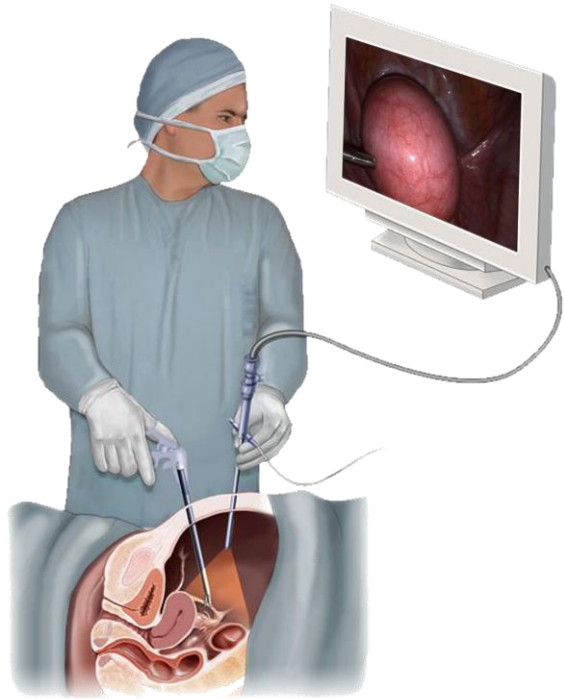
Adrien Bartoli, Nicolas Bourdel, Michel Canis, Pauline Chauvet, Toby Collins, Benoît Magnin, Daniel Pizarro

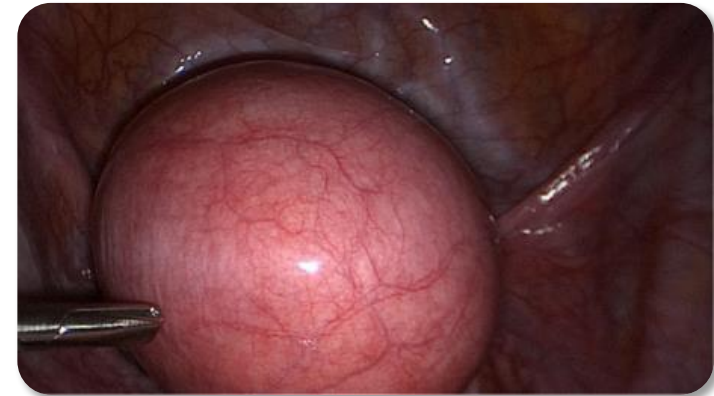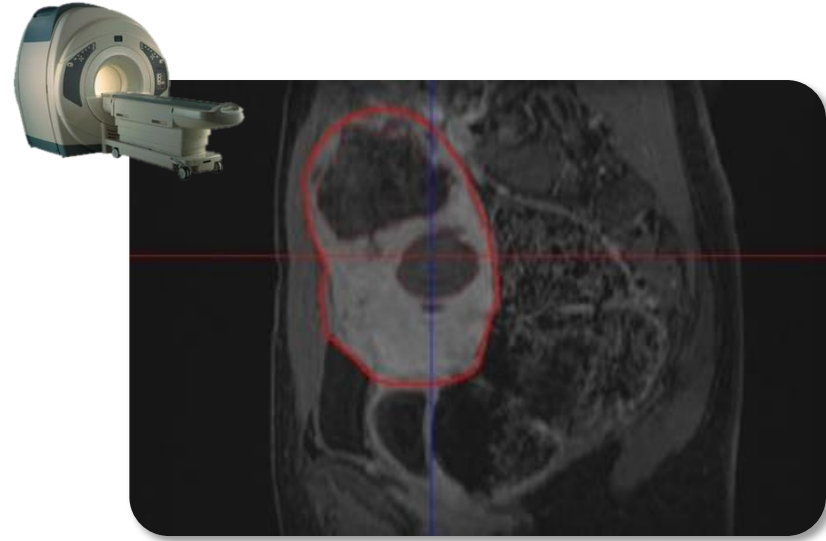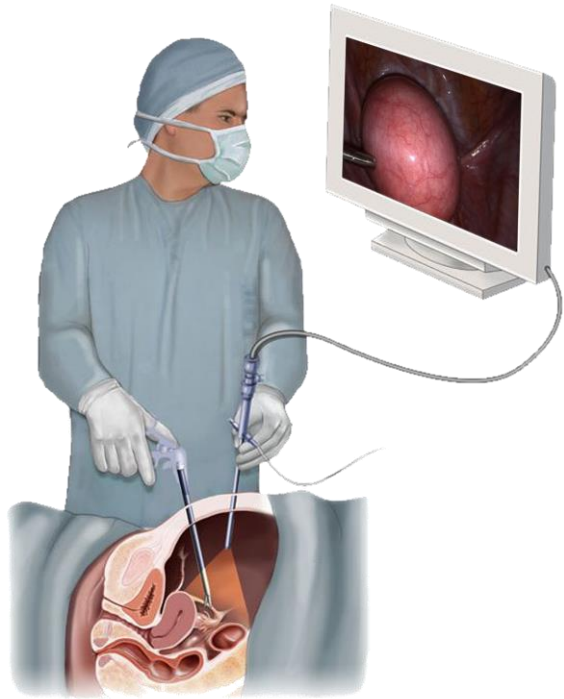*ALCoV-ISIT - UMR6284 CNRS / Université d'Auvergne*
Chirurgie gynécologique et service d'imagerie médicale et radiologie interventionnelle, CHU de Clermont-Ferrand
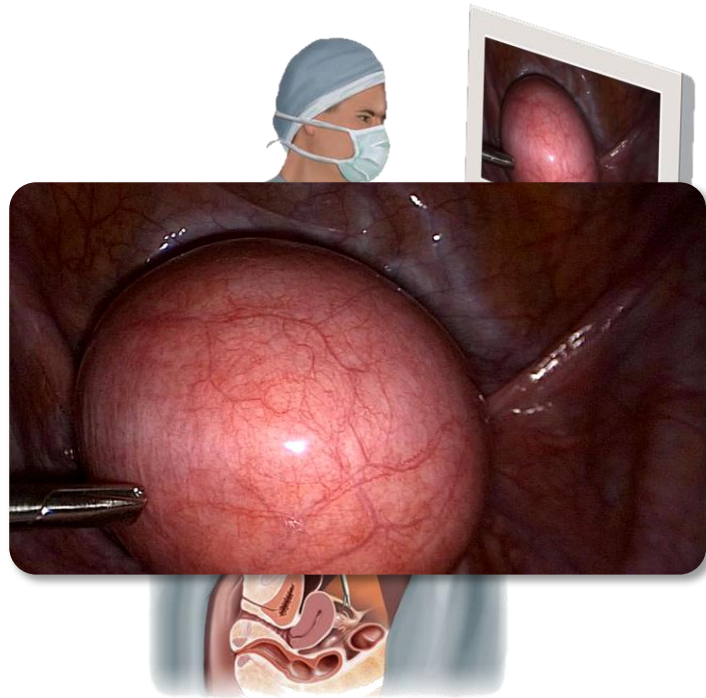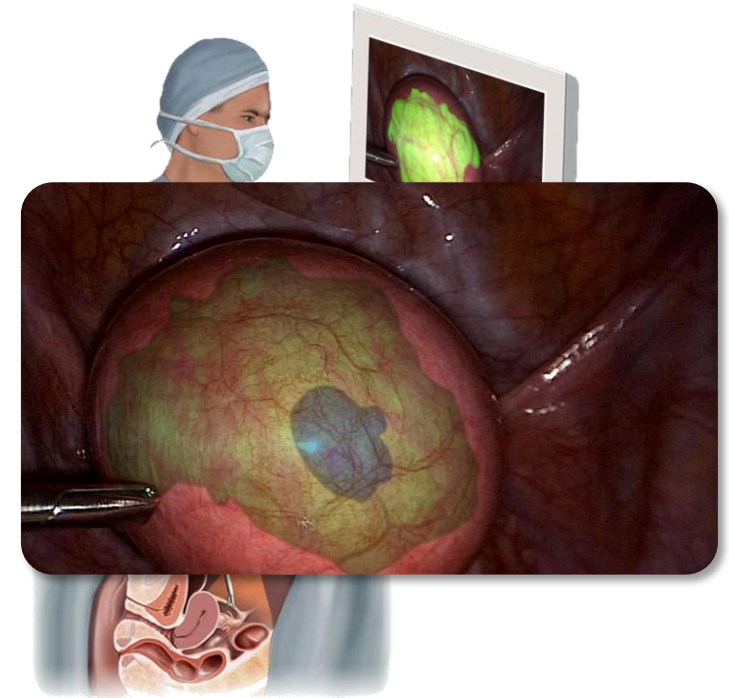
Principle of Laparosurgery

Limits of Laparosurgery

Proposed Laparosurgery Guidance System
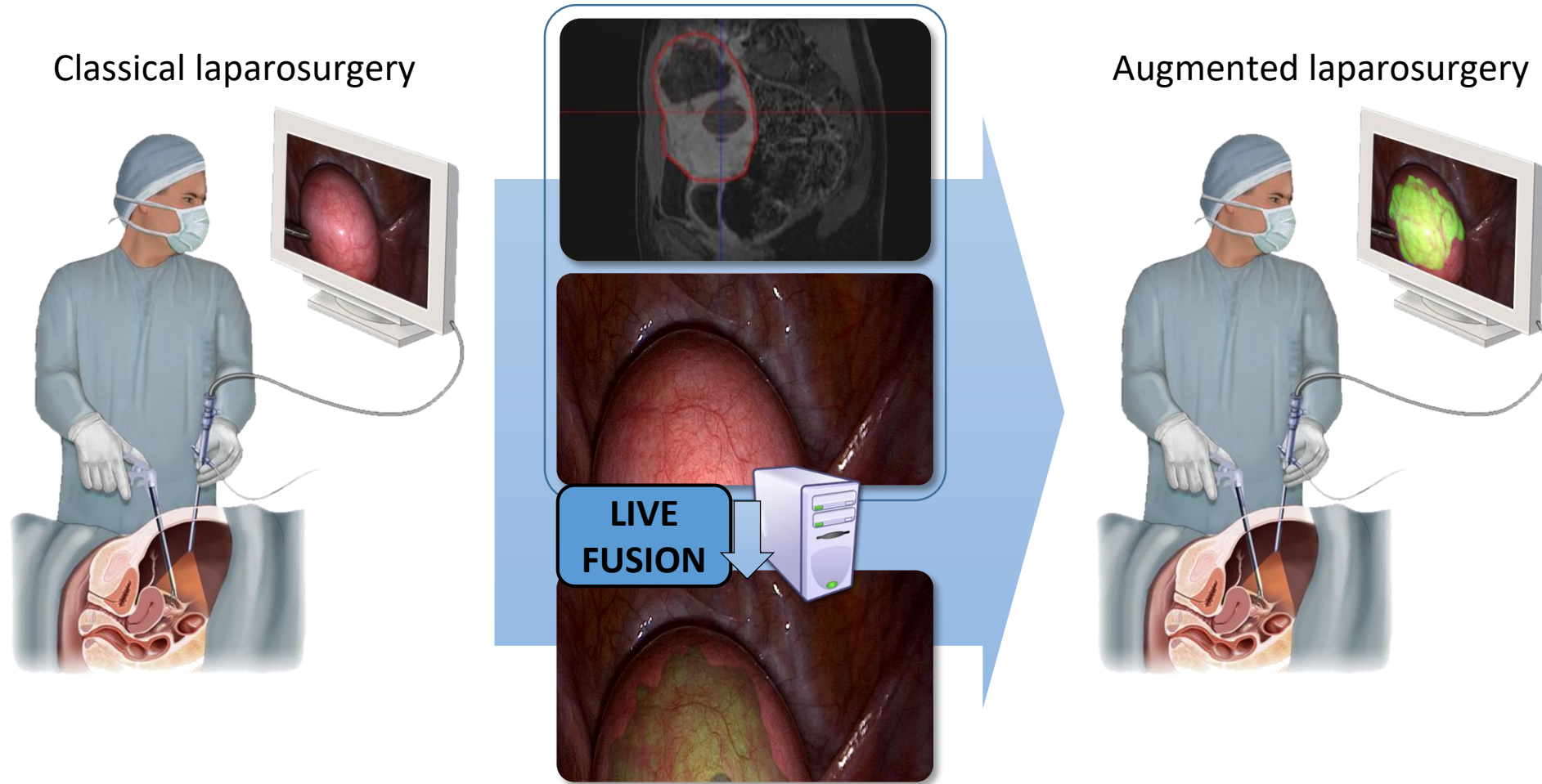

Classical laparosurgery

Augmented laparosurgery

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Augmented Reality

The Scientific Problem: What's in the Live Fusion Box?

Classical laparosurgery

Augmented laparosurgery

LIVE FUSION
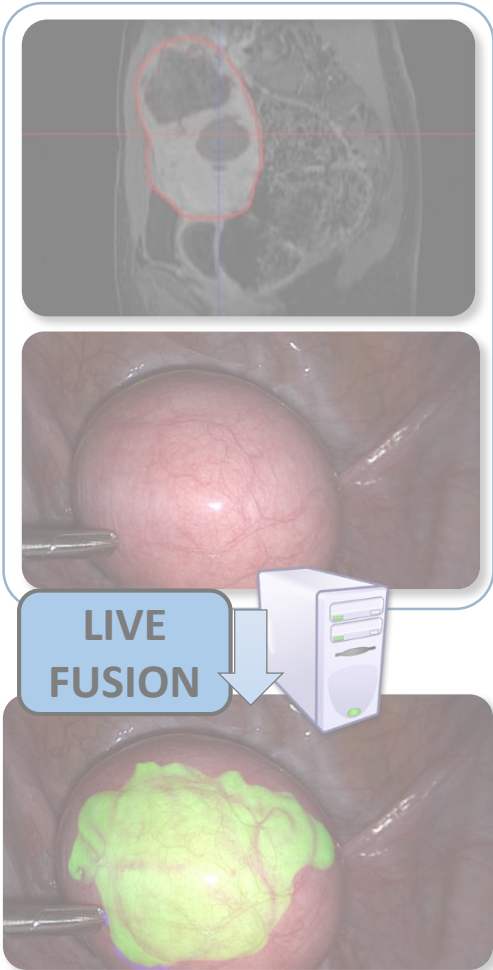
Computer Vision Problems

LIVE
FUSION
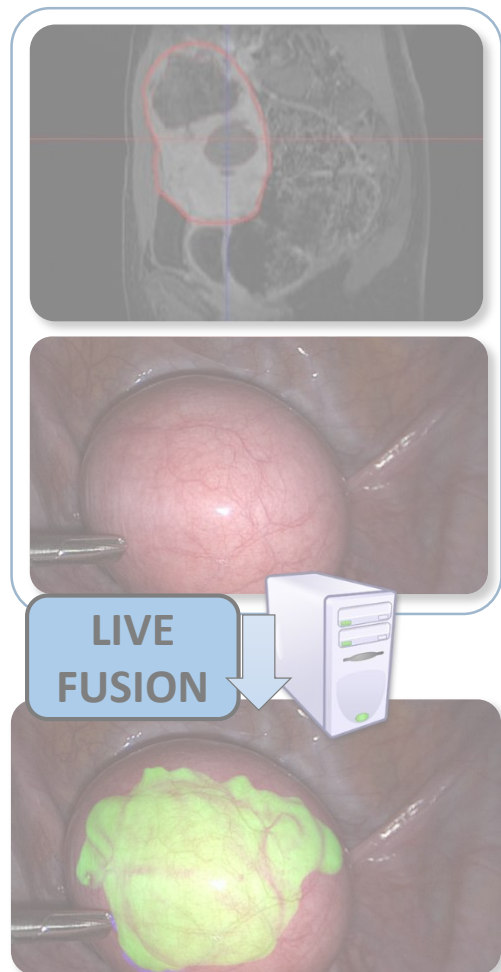
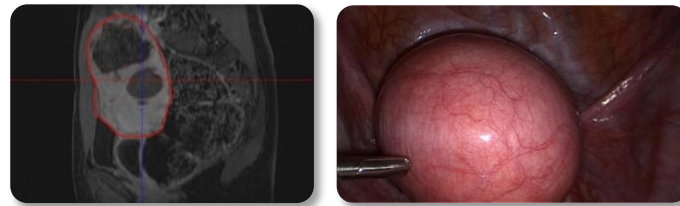Computer vision:
models and algorithms

ALCoV
I · S · I · T
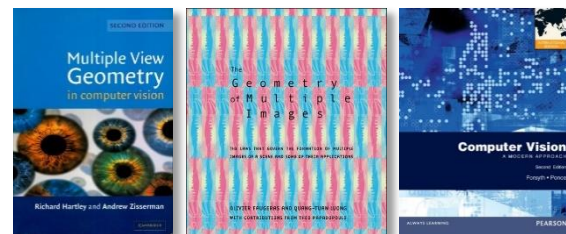
1. image understanding
2. multimodal spatial registration
3. image augmentation

Main Workflow
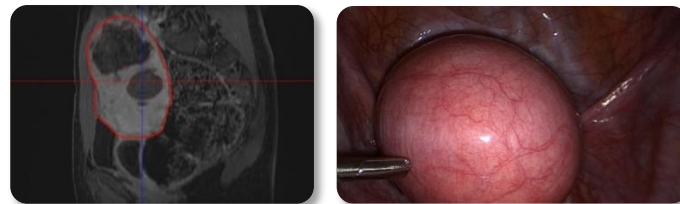

a) register

Registration requirements:
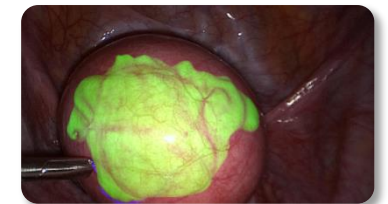 R1 – deformable   R2 – multimodal
 R3 – realtime   R4 – automatic

$\Phi_t : \mathbb{R}^3 \to \mathbb{R}^2$

b) augment
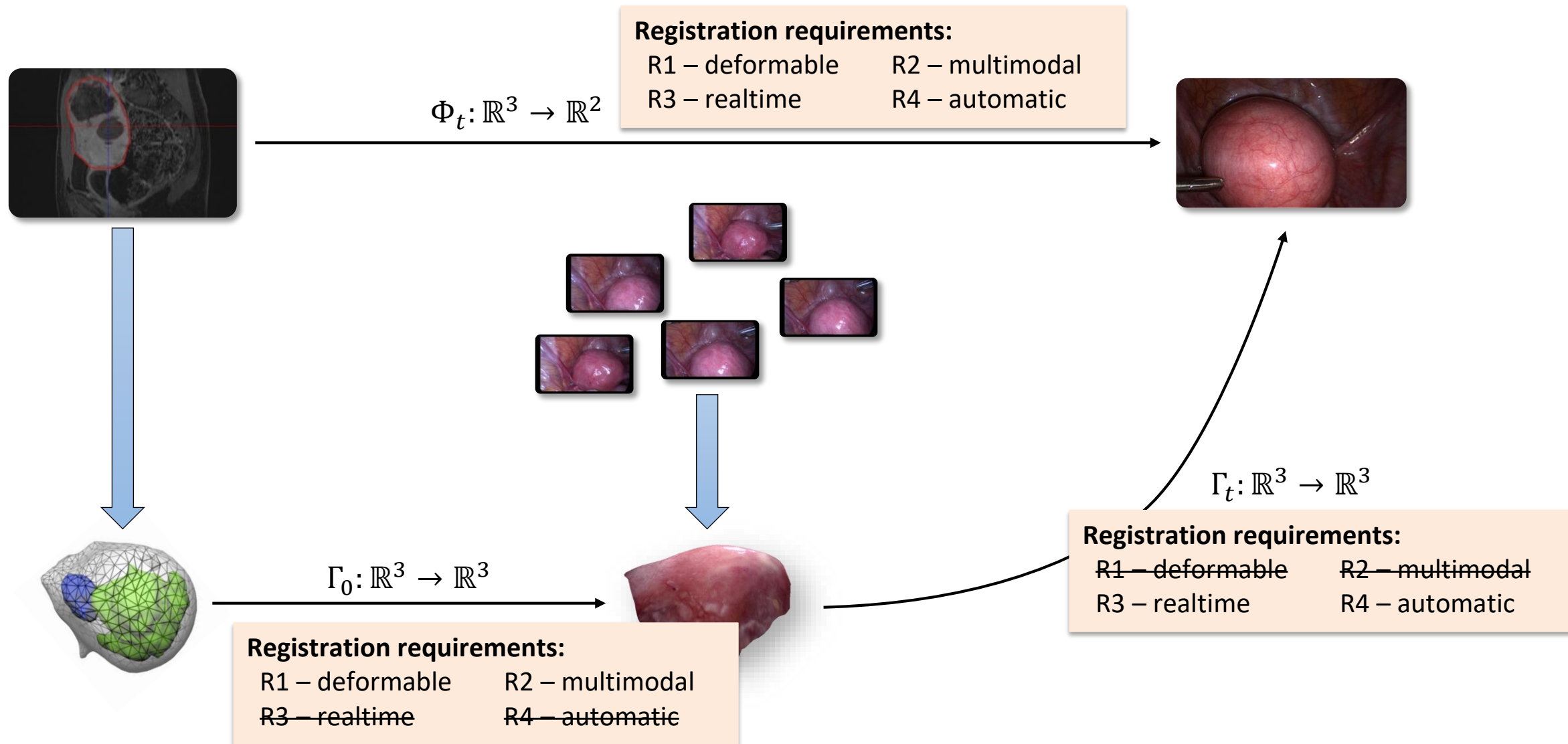
$\Phi_t : \mathbb{R}^3 \to \mathbb{R}^2$

LIVE FUSION
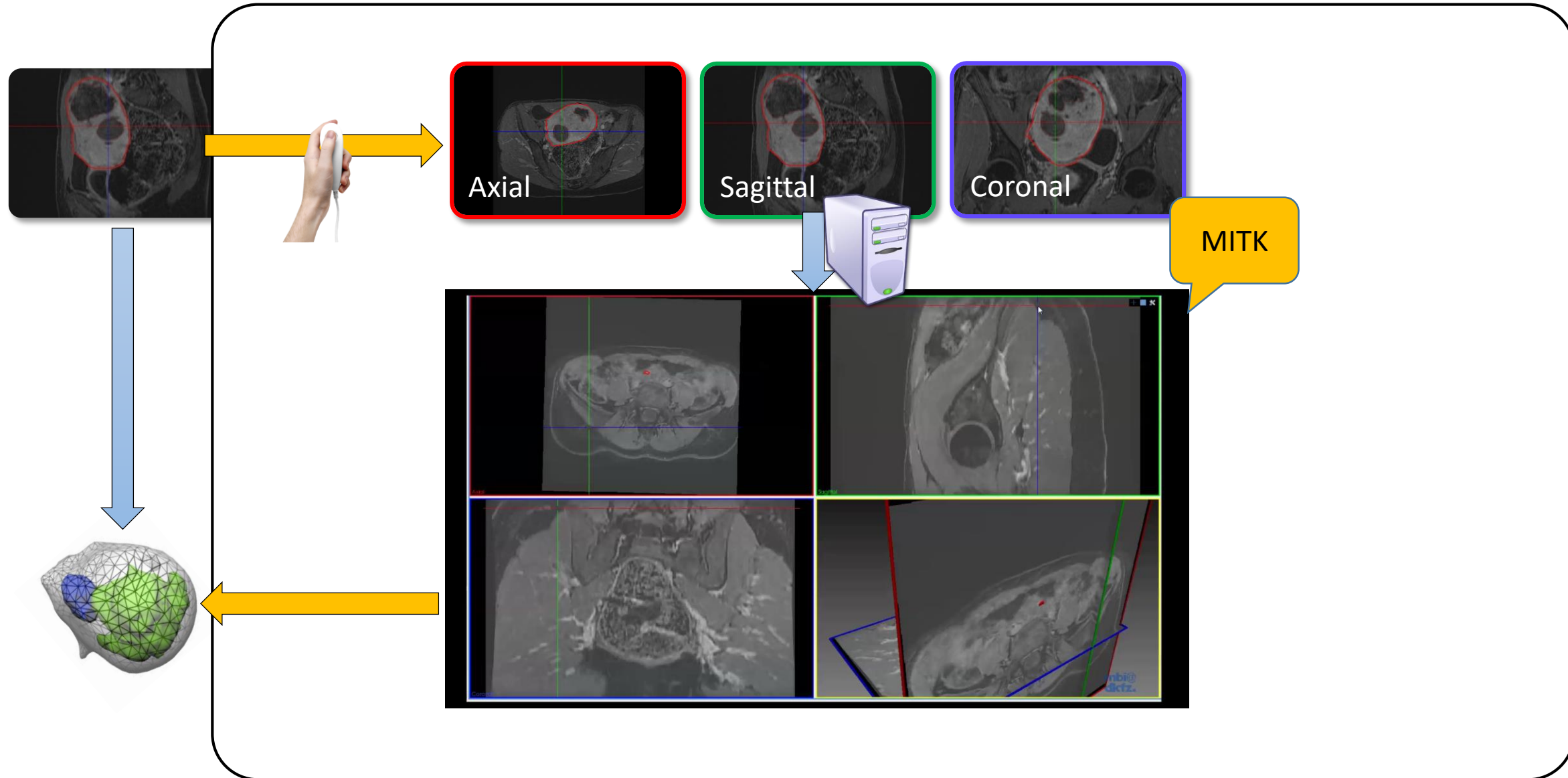
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Proposed Solution: to Decouple Registration in Two Parts

$\Phi_t: \mathbb{R}^3 \to \mathbb{R}^2$

Registration requirements:

R1 – deformable   R2 – multimodal

R3 – realtime   R4 – automatic

$\Gamma_0: \mathbb{R}^3 \to \mathbb{R}^3$

Registration requirements:

R1 – deformable   R2 – multimodal

~~R3 – realtime~~   ~~R4 – automatic~~

$\Gamma_t: \mathbb{R}^3 \to \mathbb{R}^3$

Registration requirements:

~~R1 – deformable~~   ~~R2 – multimodal~~

R3 – realtime   R4 – automatic

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Preoperative 3D Model Construction

Axial

Sagittal

Coronal

MITK

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Intraoperative 3D Reference Model Reconstruction

$\Phi_t: \mathbb{R}^3 \to \mathbb{R}^2$

Registration req
R1 – deformable
R3 – realtime

Uterine cannula

SfM

$\Gamma_0: \mathbb{R}^3 \to \mathbb{R}^3$

Registration requirements:

R1 – deformable   R2 – multimodal

R3 – realtime   R4 – automatic

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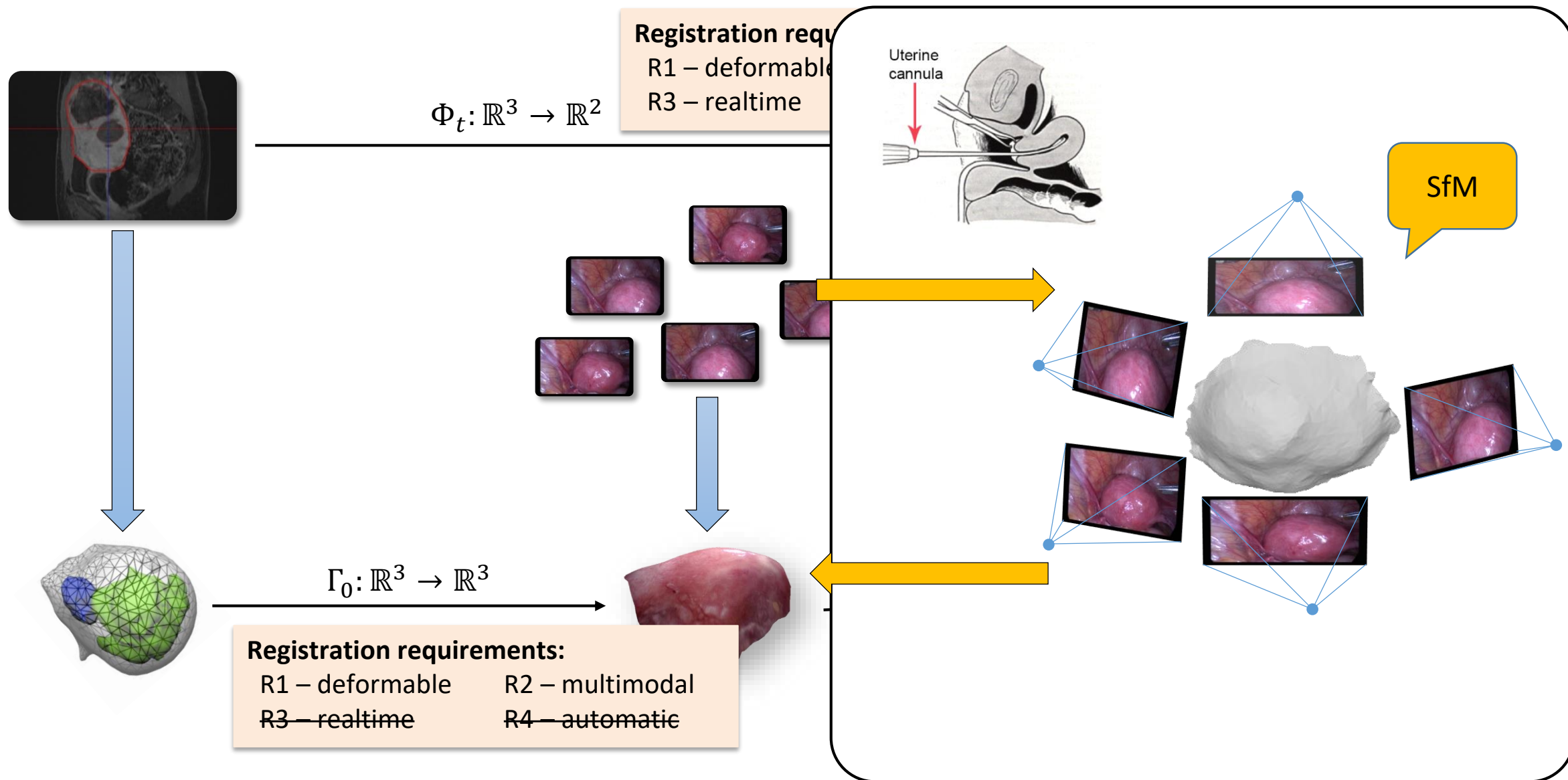
Preoperative to Intraoperative-Reference Registration

Registration requirements:
R1 – deformable   R2 – multimodal
R3 – realtime   R4 – automatic

Proposed technique

$\mathbb{R}^2$

$\Gamma_0: \mathbb{R}^3 \rightarrow \mathbb{R}^3$

$\Gamma_t: \mathbb{R}^3 \rightarrow \mathbb{R}^3$

Registration requirements:
R1 – deformable   R2 – multimodal
~~R3 – realtime~~   ~~R4 – automatic~~

Registration requirements:
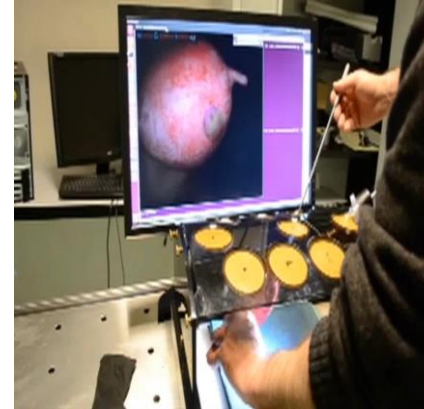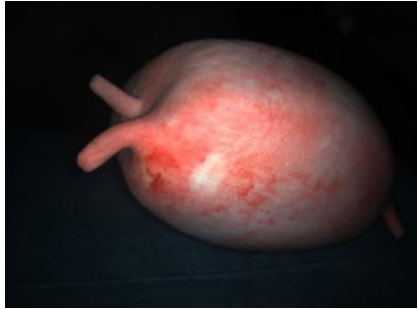~~R1 – deformable~~   ~~R2 – multimodal~~
R3 – realtime   R4 – automatic

ALCoV
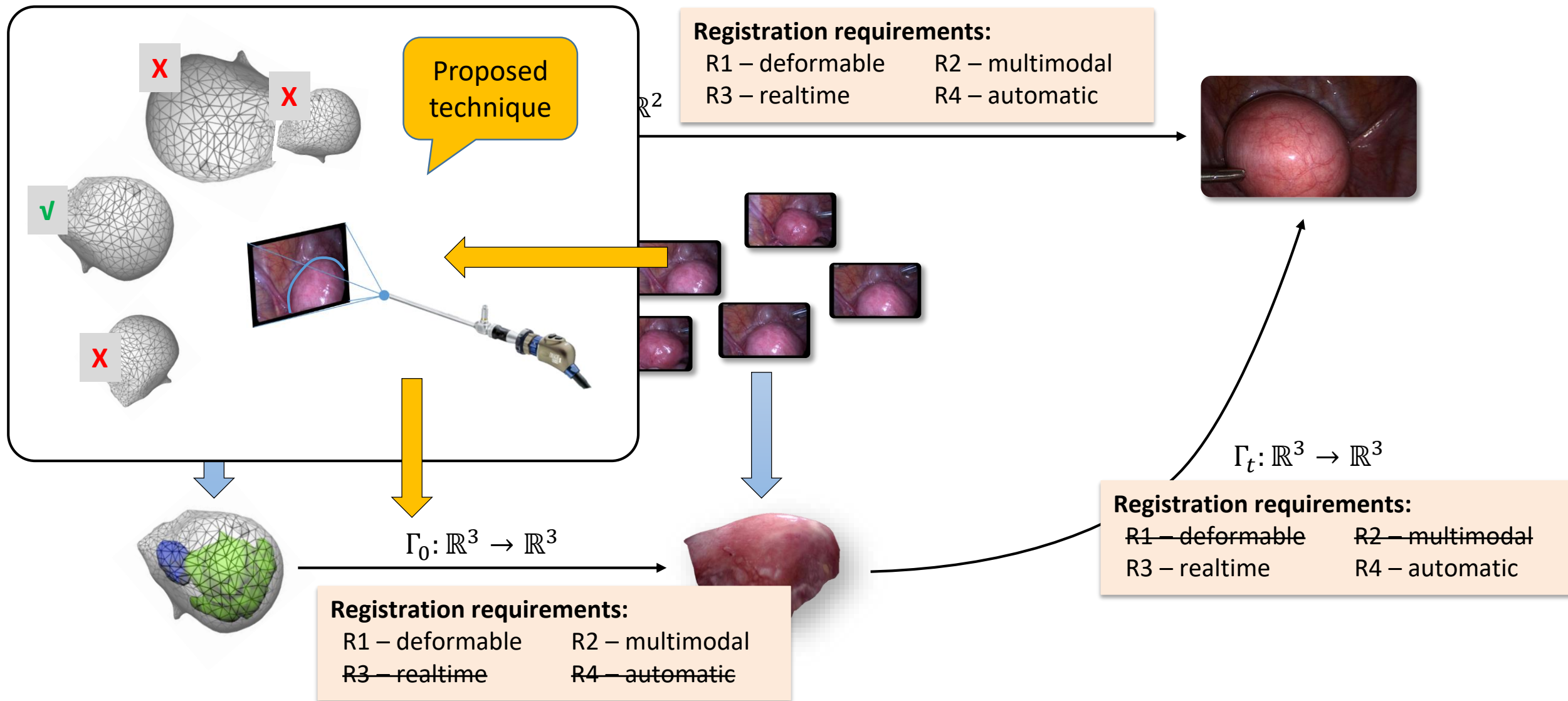
# Intraoperative Registration Update
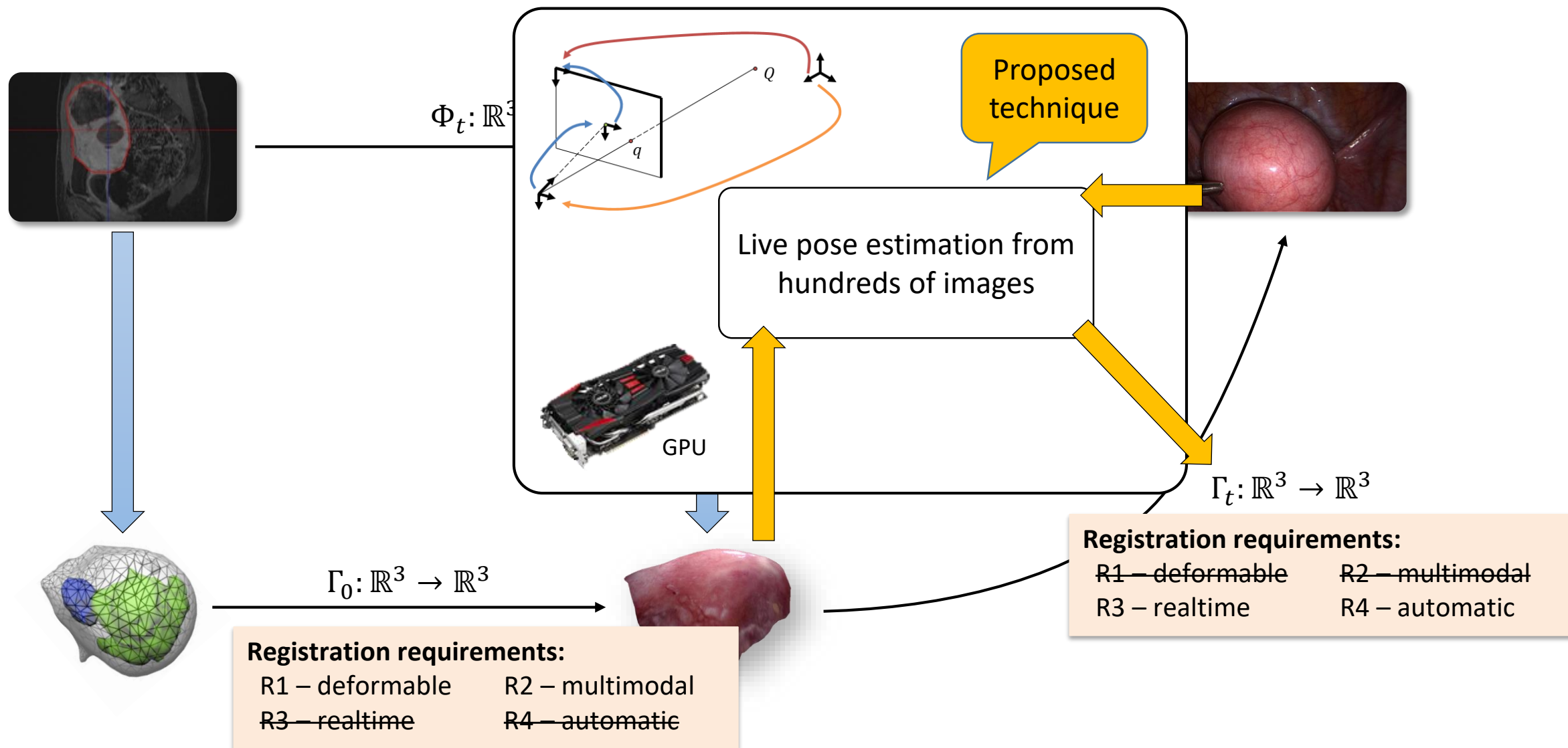
Clinical Use
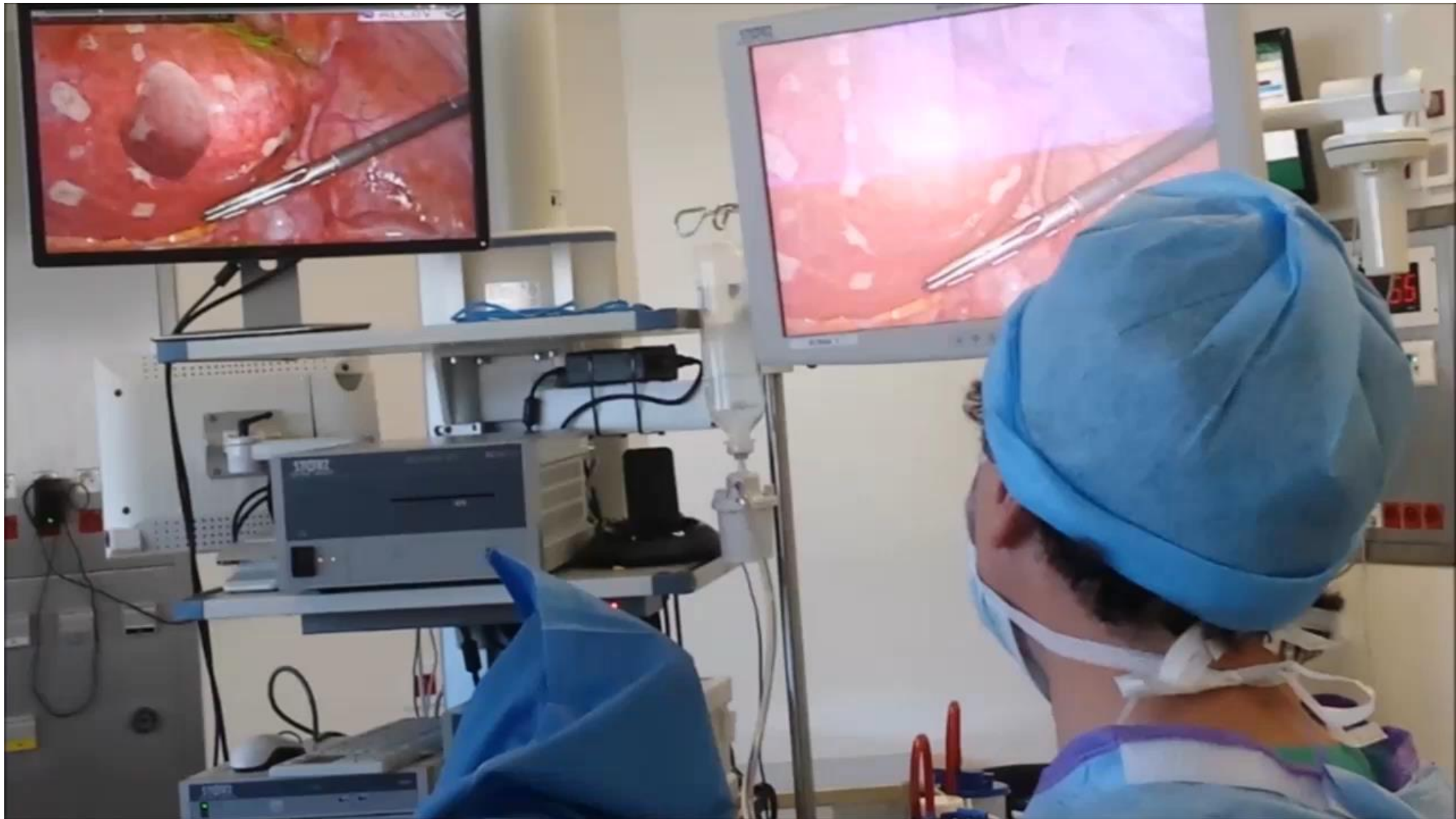
Phantom Myomectomy
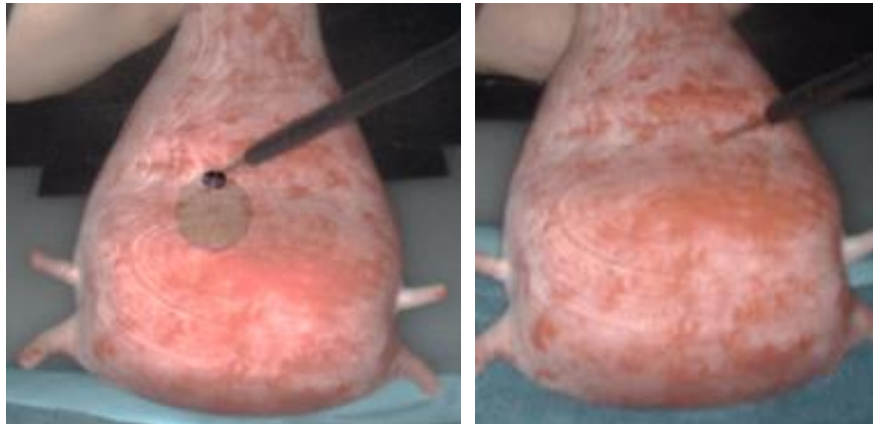
Localisation is 20 times more accurate with augmented laparoscopy

Augmented reality in gynecologic surgery: evaluation of potential benefits for myomectomy in an experimental uterine model

Nicolas Bourdel[1,2] · Toby Collins[2] · Daniel Pizarro[2] · Adrien Bartoli[2] ·
David Da Ines[2,3] · Bruno Perreira[4] · Michel Canis[1,2]

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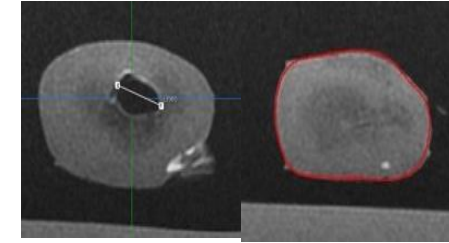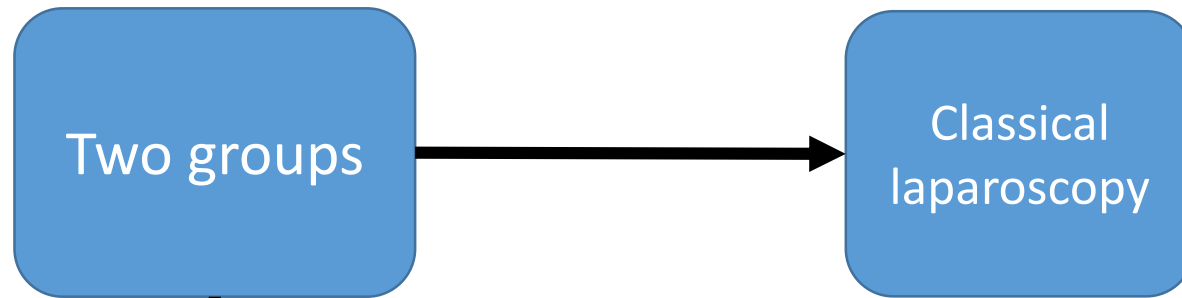# Evaluation on Phantom Tumours in Ex-vivo Porcine Kidneys

- Creation of tumours with Alginate
- MRI scan
- Ablation by laparoscopy

Goal: to evaluate the quality of surgery
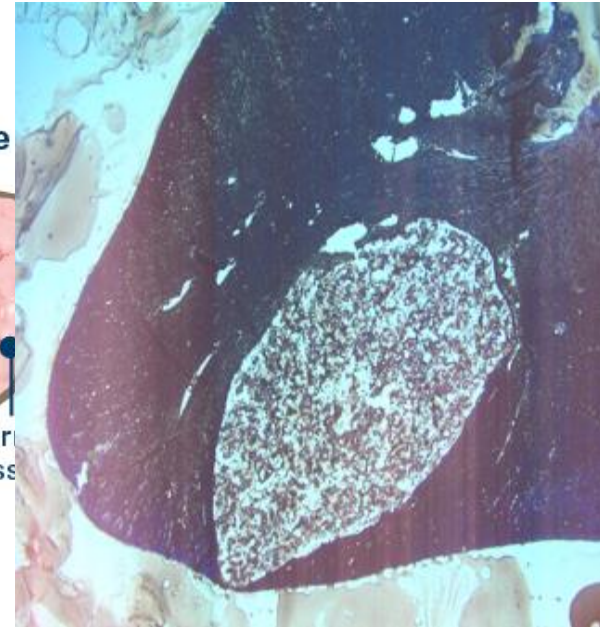
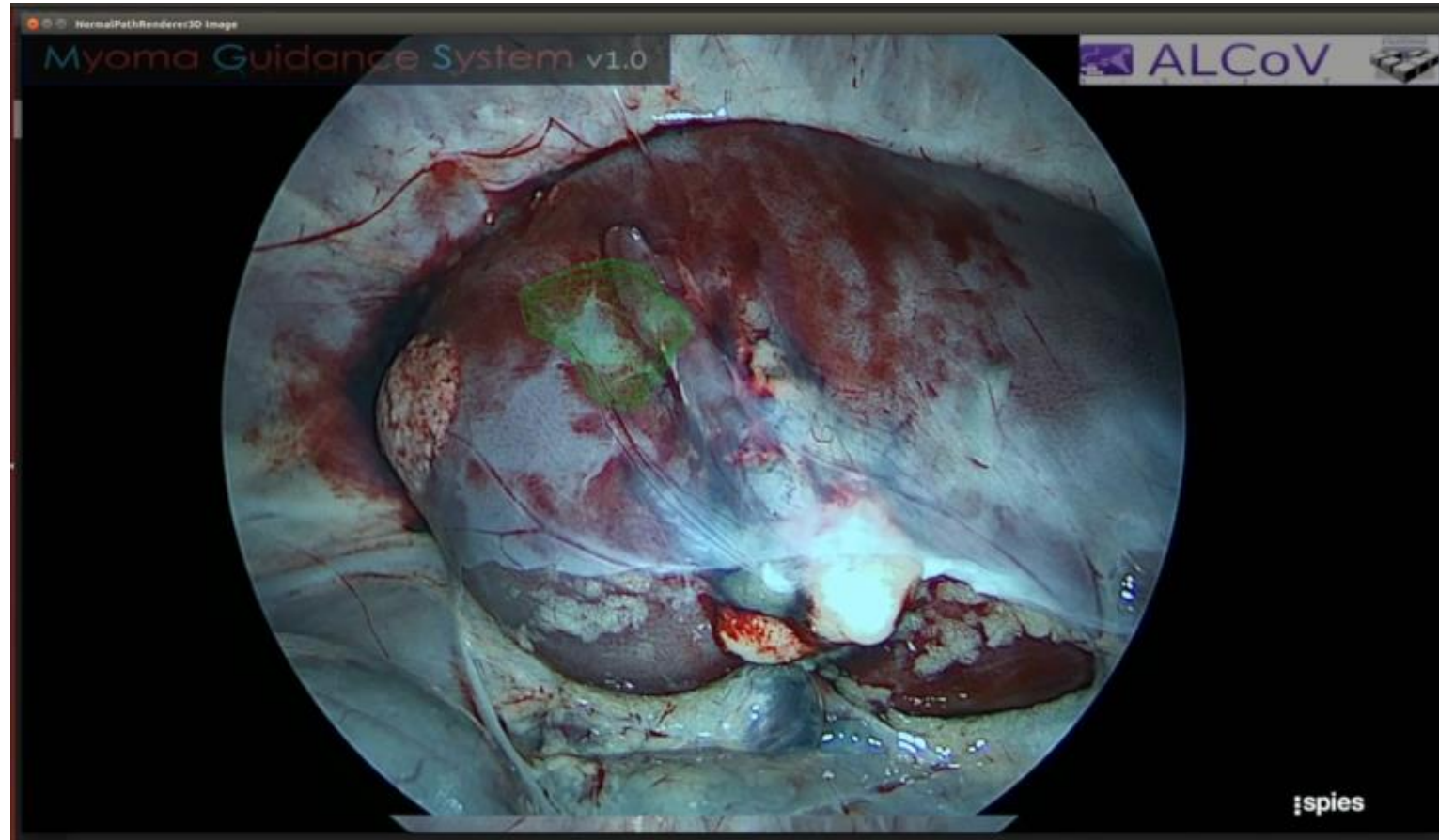# Evaluation on Phantom Tumours of Ex-vivo Porcine Kidneys

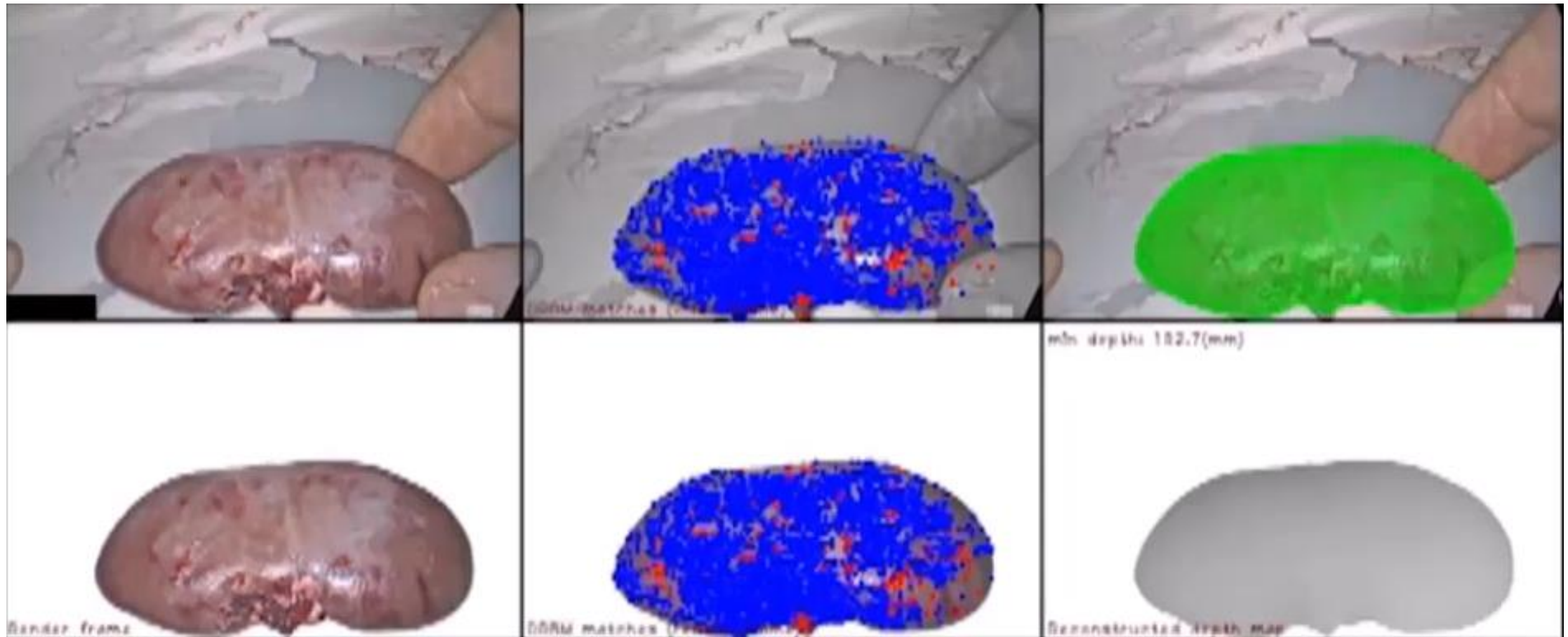Two groups → Classical laparoscopy

Augmented laparoscopy
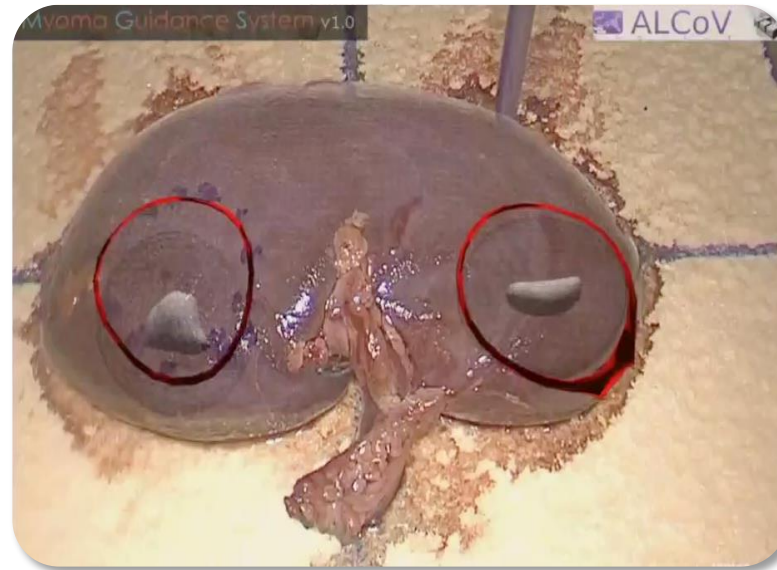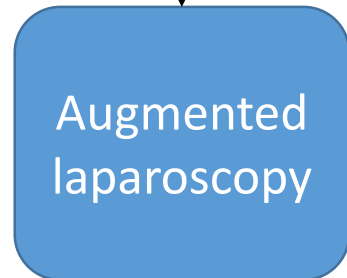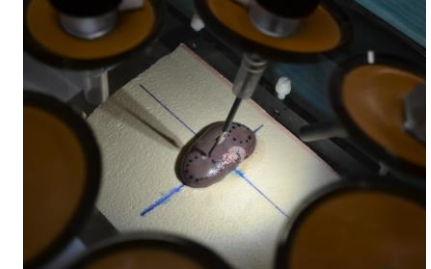
Augmented laparoscopy improves the quality of resection, with a success rate of 85.2% versus 41.9%
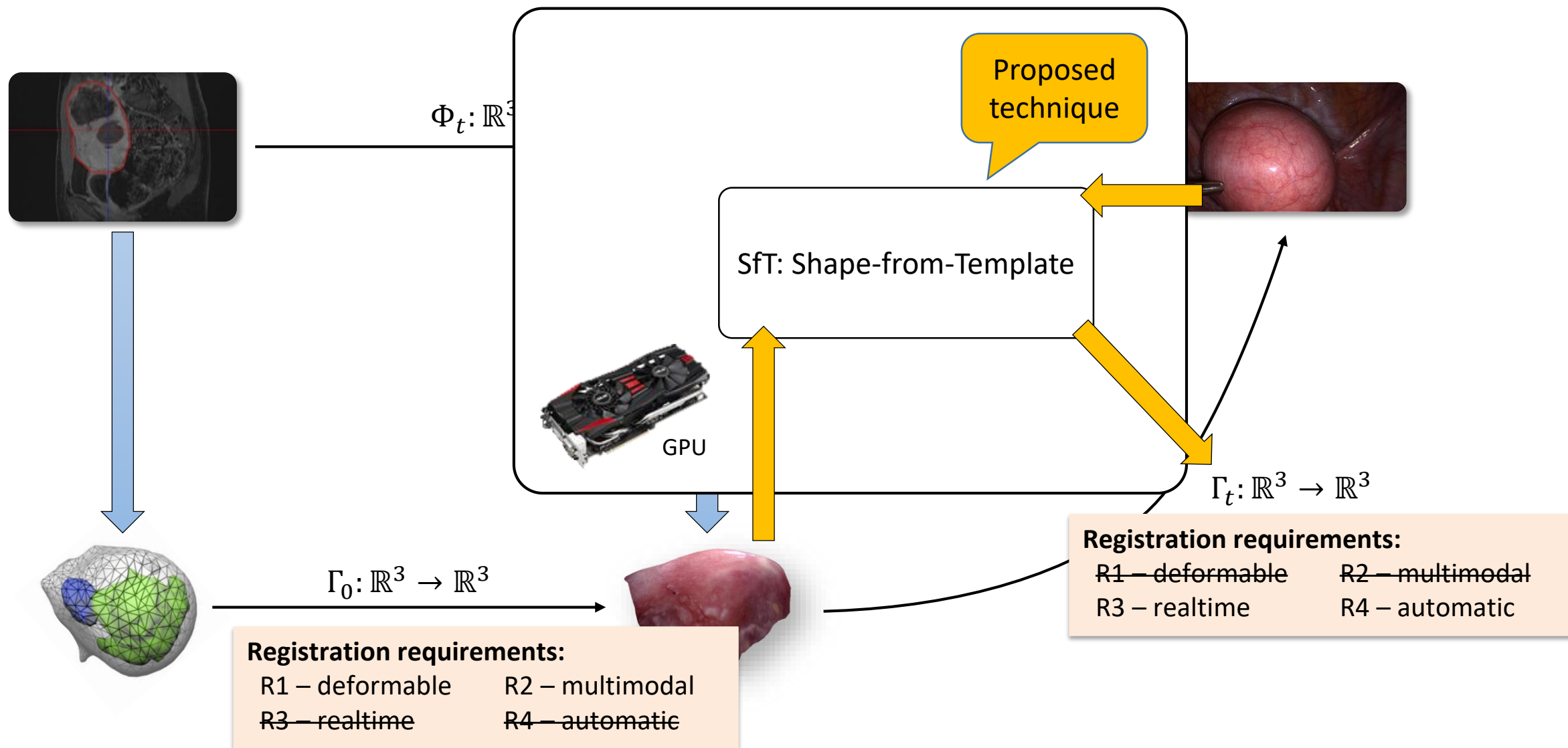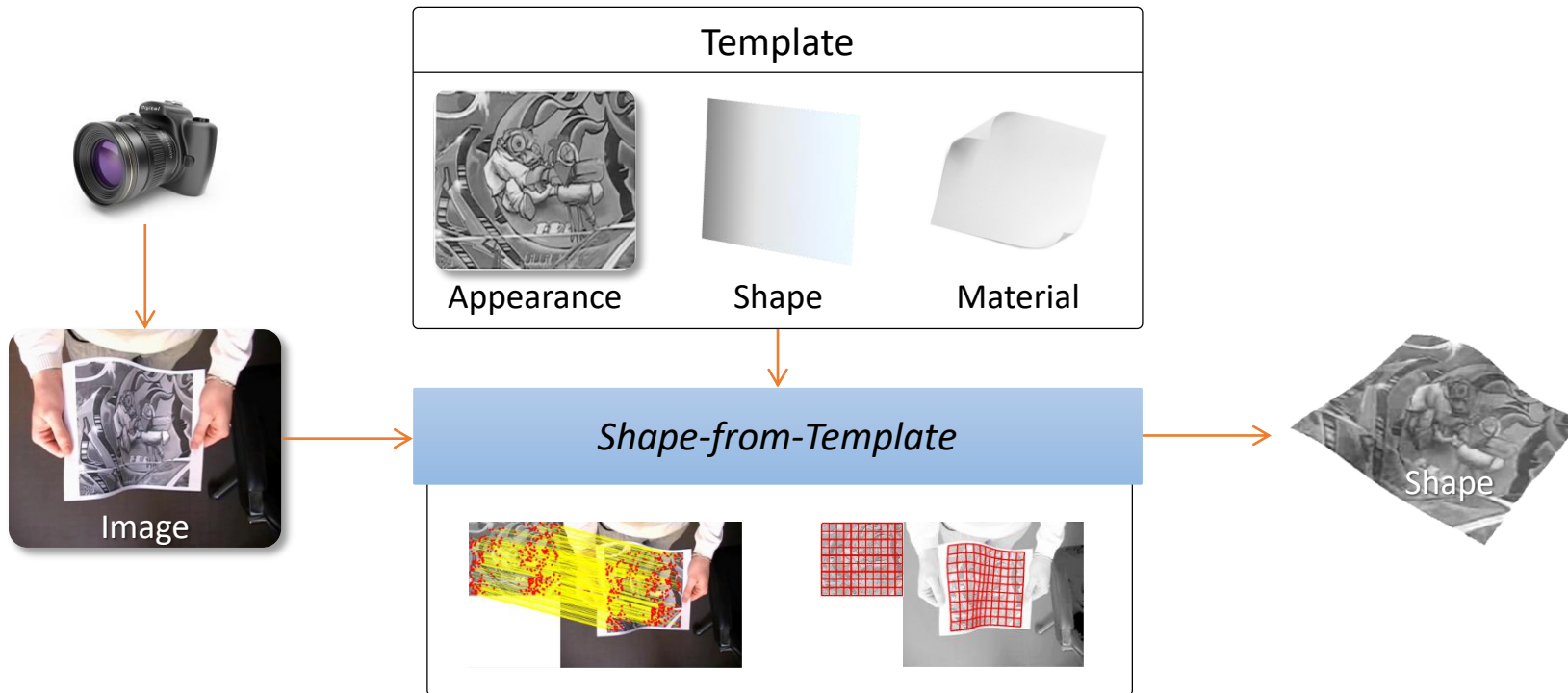
In-vivo Porcine Kidney

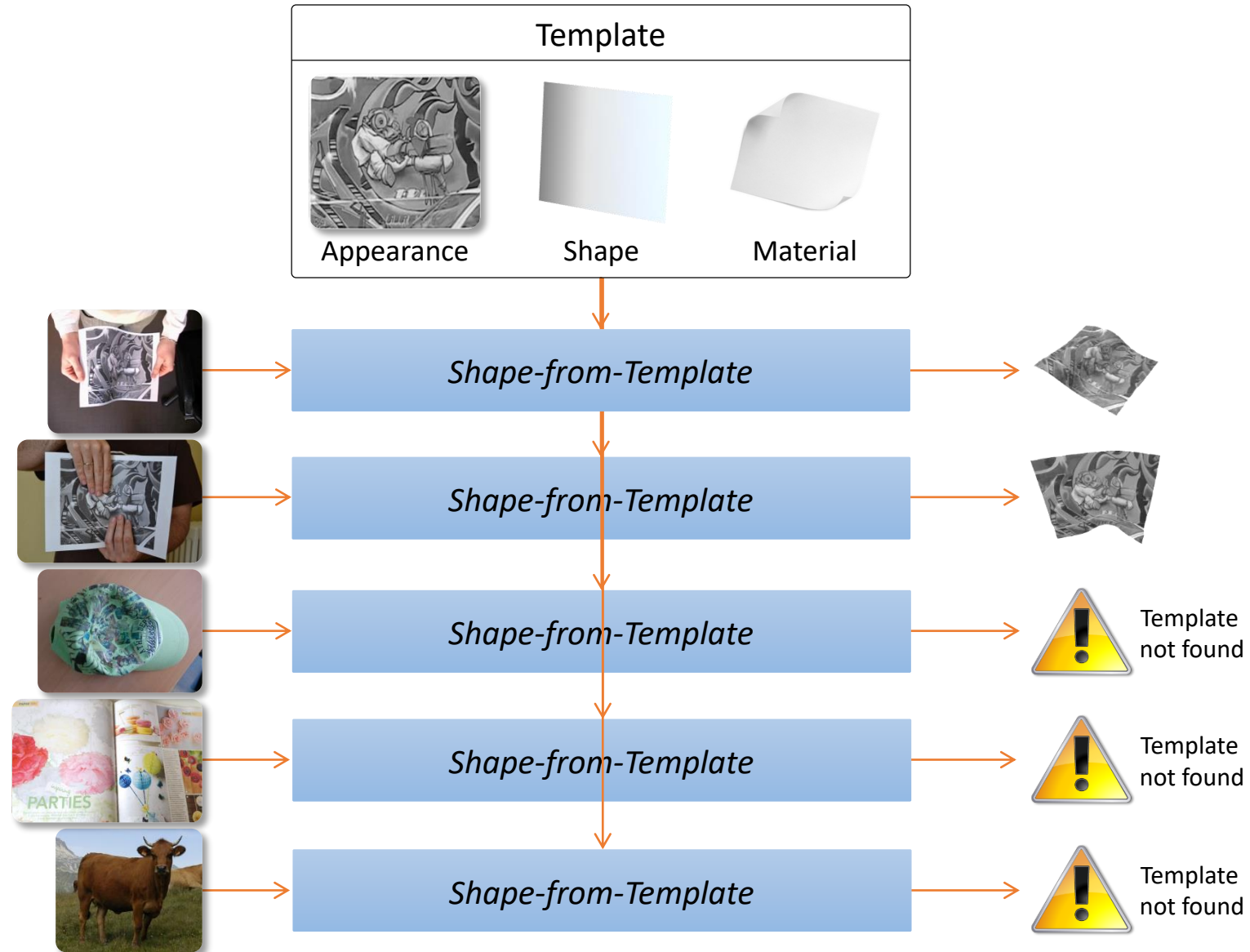# Intraoperative Deformable Tracking of an Ex-vivo Porcine Kidney
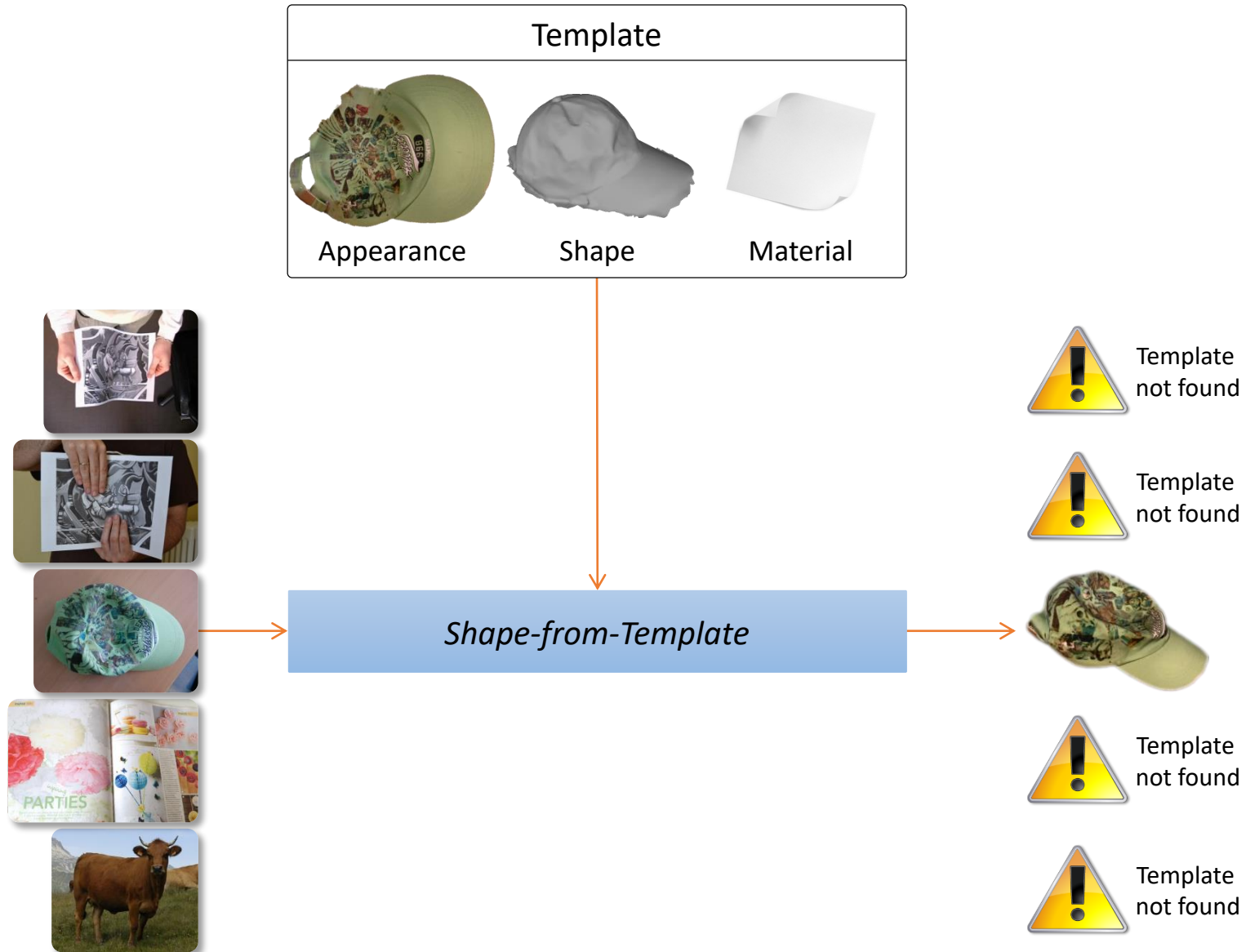
Intraoperative Deformable Registration Update by SfT

Shape-from-Template

Template

Appearance · Shape · Material

Shape-from-Template

Image

Shape

Shape-from-Template

Shape-from-Template

Shape-from-Template Facts

- Barely 10 years old

- Theory based on PDE

- Fast wide-baseline algorithms

- Realtime tracking algorithms

- Effective for near-isometry

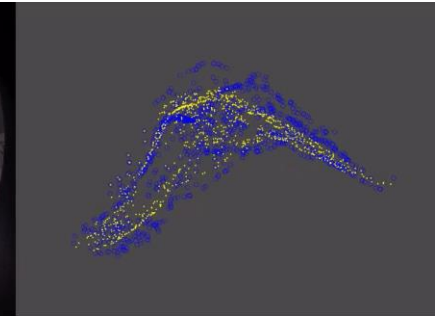# Non-Rigid Shape-from-Motion
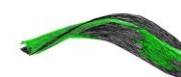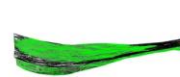

Erreur : 5.39 mm

Erreur : 9.12 mm

Erreur : 8.14 mm

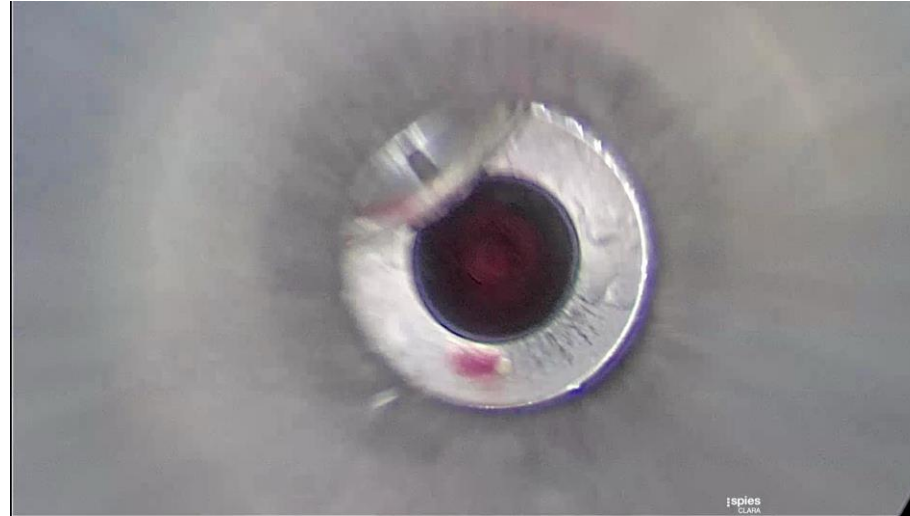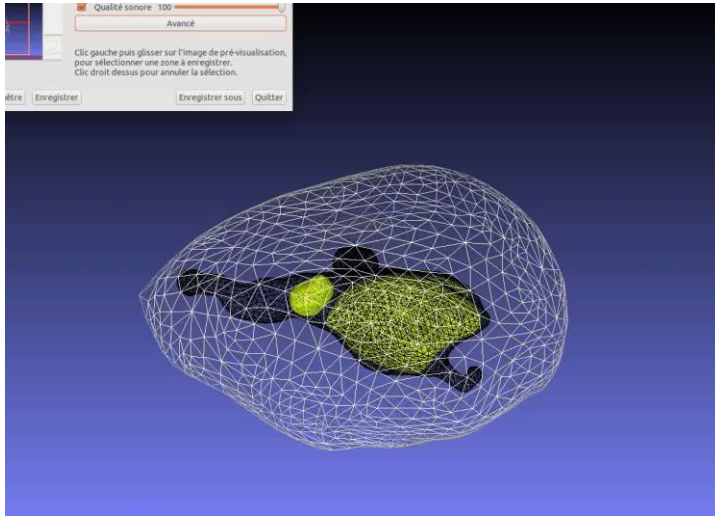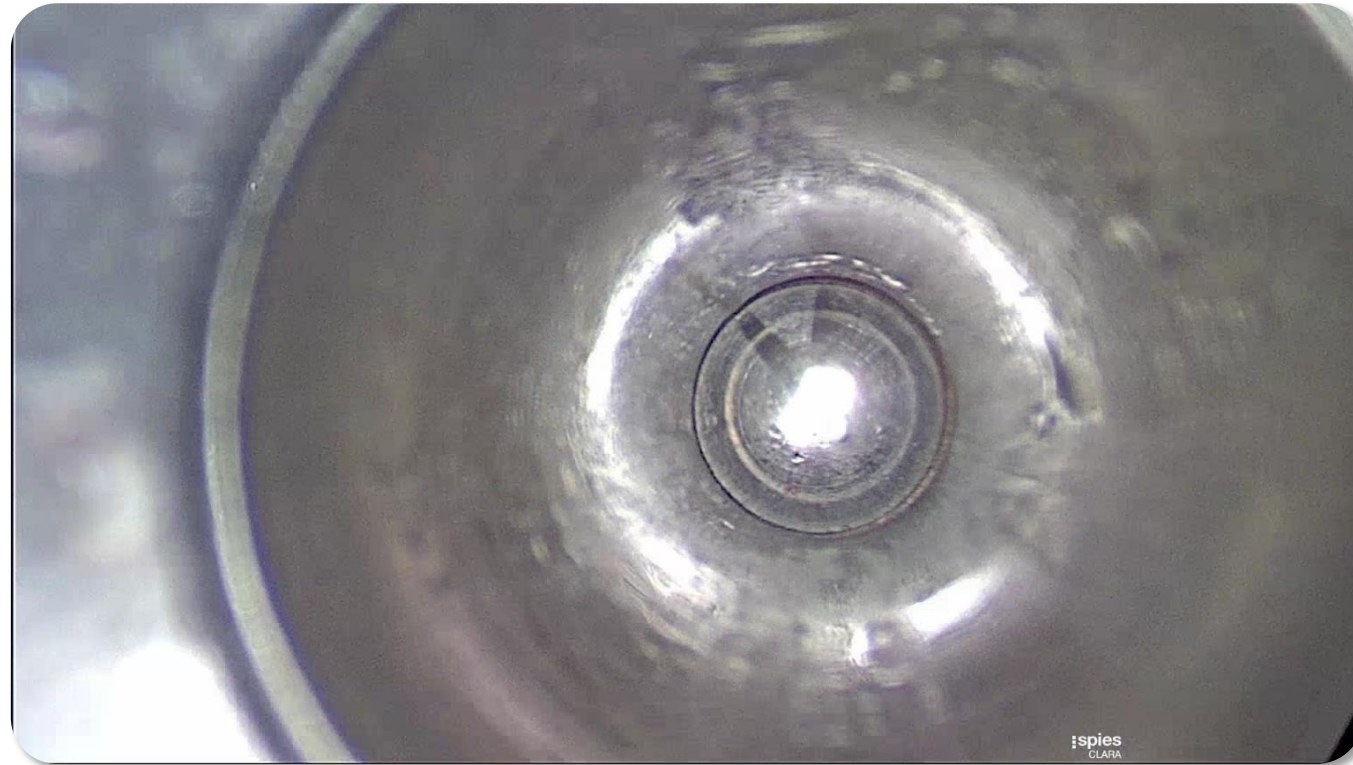Reconstruction   Vérité terrain   Erreur : 3.23 à 5.72 mm

Reconstruction

Vérité terrain

Erreur : 4.55 à 6.50 mm

Current Working Prototype

Computer-Aided Surgery of the Uterus by Augmenting the Live Laparoscopy Stream with Preoperative MRI Data