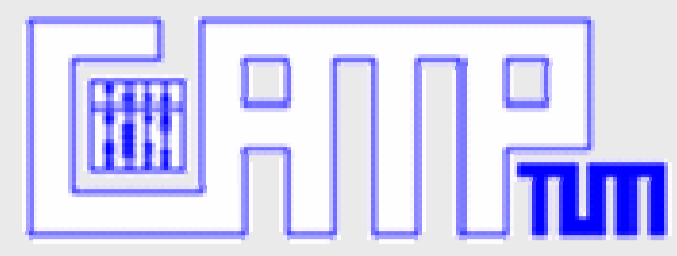


# Automatic Patient Registration for Port Placement in Minimally Invasive Endoscopic Surgery



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## Problem Statement

- Endoscopic surgery implies a precise selection of instruments' ports to provide:
  - Full access to the whole operating region
  - Adequate surgeon dexterity
- The limited endoscopic view constrains the surgeon

## Previous Approaches

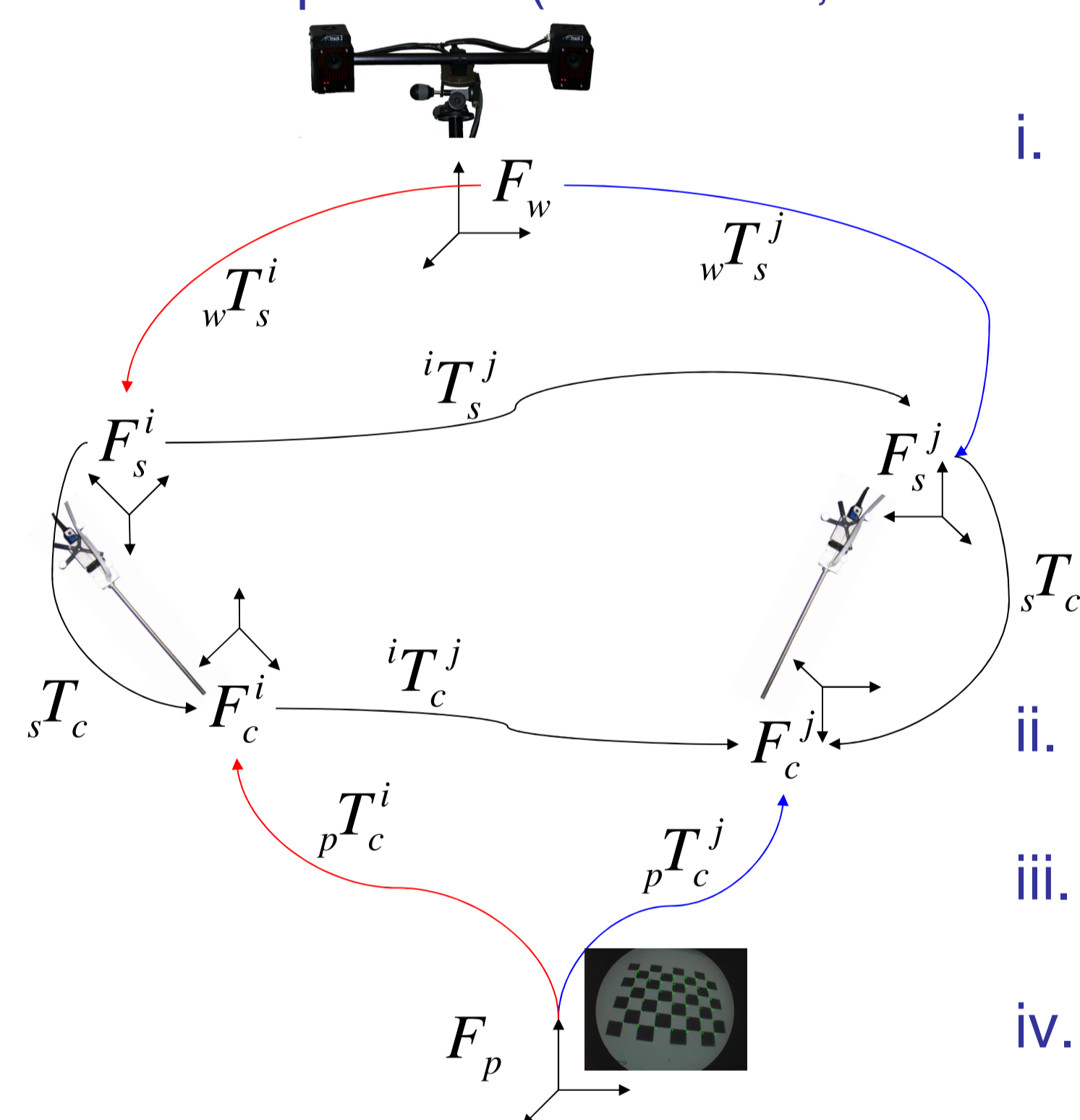
- Manual segmentation and reconstruction of polygonal models of the patient's anatomy
- Interactive definition of a region of interest
- Computation of ports based on assumptions for a particular intervention
- Matching of manually selected or interactively touched anatomical or artificial landmarks to register the patient to its pre-operative data [Adhami et al, MICCAI 2002; Chiu et al, HSF 3:3, 2000; Selha et al, SPIE TTT VIII, 2002]

### Two major disadvantages:

- Time-consuming manual or semi-automatic segmentation
- No practical and accurate way to transfer the planned ports to the operating room

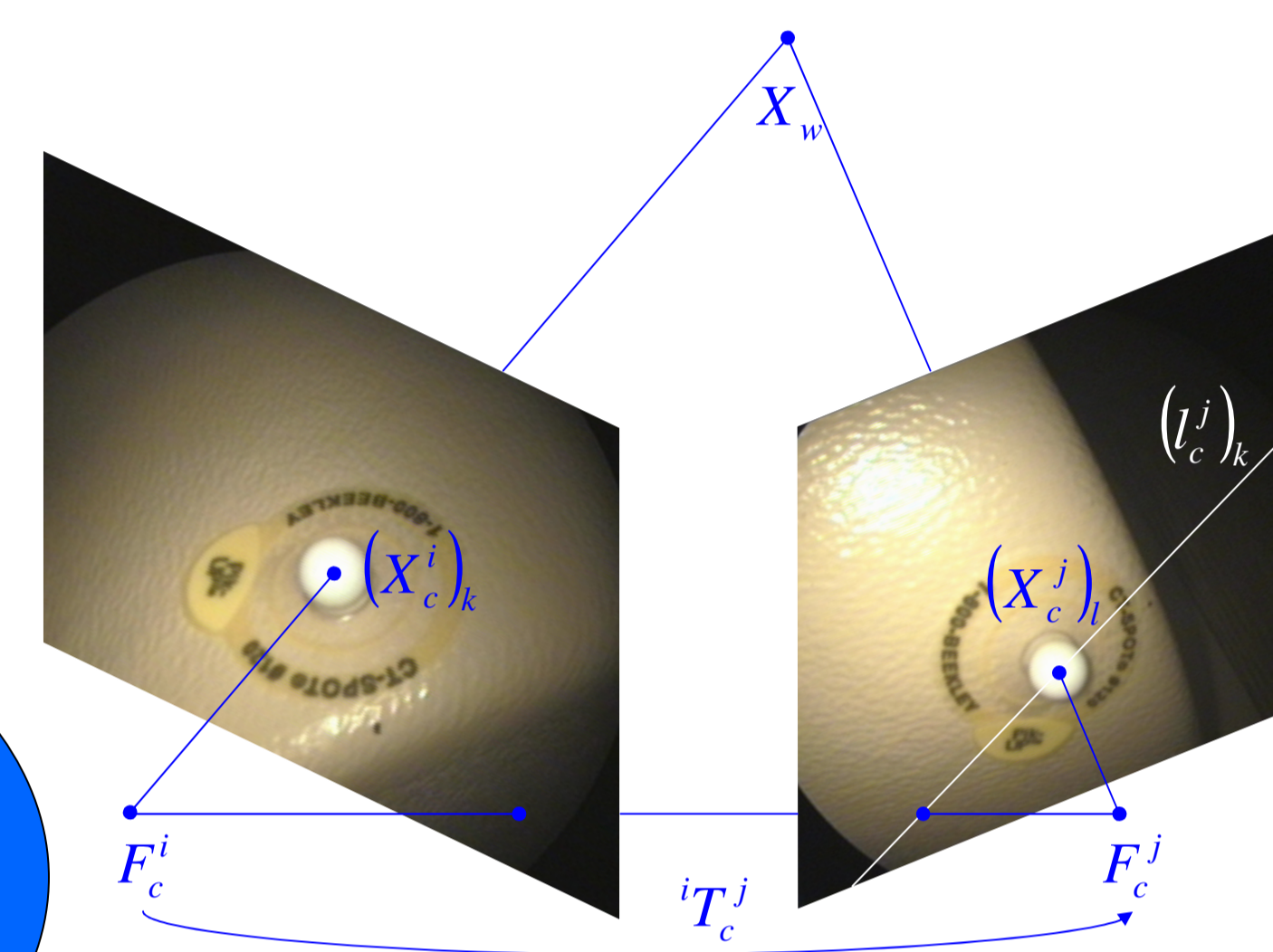
## 1 Off-line Calibration

- Estimation of camera intrinsics by conventional camera calibration  $\mathbf{x} = \mathbf{K}_s \mathbf{T}_{c w} \mathbf{T}_s \mathbf{X}_w$
- Computation of the missing constant transformation between the endoscope and camera coordinate system by hand-eye calibration
  - Prerequisite: A corresponding set of camera poses in the pattern coordinate system and endoscope poses in the tracking coordinate system  ${}^s\mathbf{T}_c {}^i\mathbf{T}_s^j = {}^i\mathbf{T}_c^j {}^s\mathbf{T}_c$
  - Computations based on dual quaternions and matrix decomposition (Tsai/Lenz, Daniilidis)



## 2 Pre-operative CT

- CT of patient with CT visible self-adhesive spherical fiducials stuck on the patient's skin
- Automatic marker extraction



## Our Approach

## 4 Port Placement and Simulation

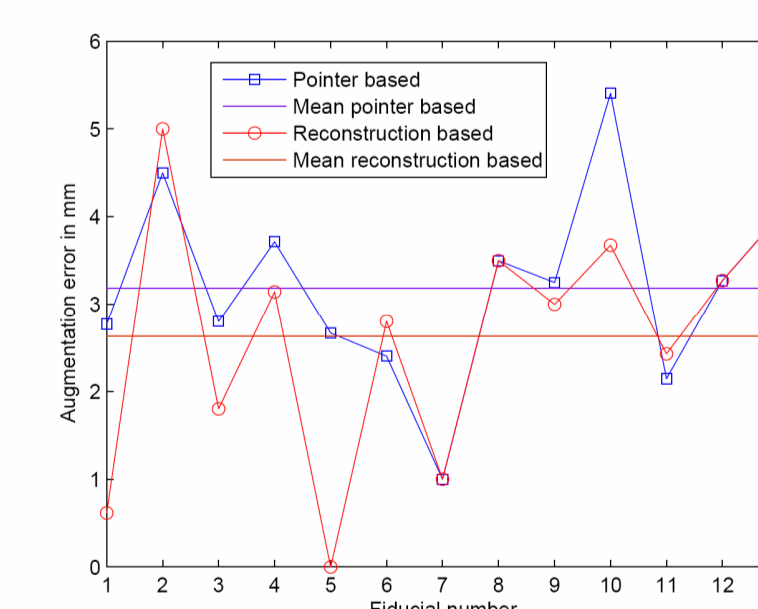
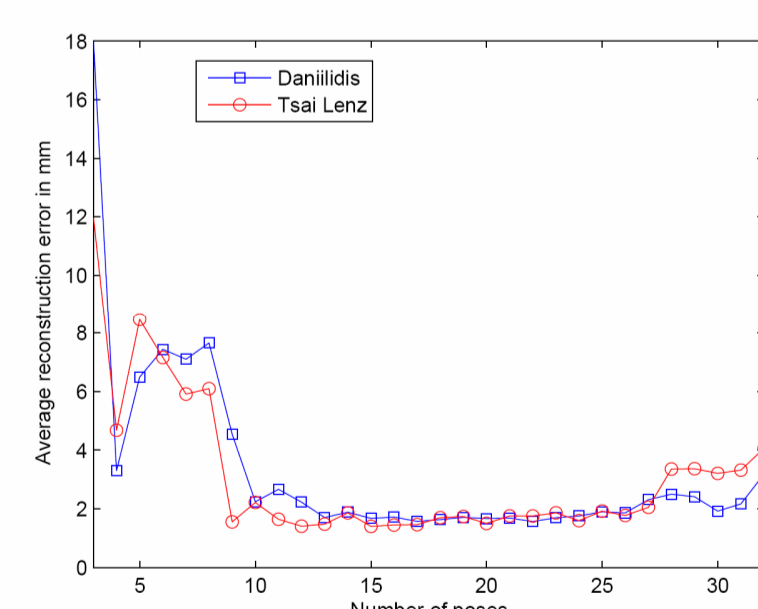
- Virtual endoscopy prior to the intervention:
  - Real, augmented, and virtual mode available from any camera pose
  - Patient fly-through: Movement of a virtual camera with 0° or 30° optics along its main axis into the patient to verify the current port (not only applicable to the endoscope, but also to instruments)
- Improved intra-operative navigation by zooming in and out the current view
- No segmentation due to GPU based direct volume rendering of the CT
- Provision of transfer functions to realistically map image intensities to natural and more intuitive colors

## 3 Automatic Patient Registration

- Automatic detection of each fiducial in the endoscope images during endoscope movements around the patient
- Automatic reconstruction of its 3D position based on triangulation, using the current tracking data and previously computed camera parameters
- Refinement of its 3D position by applying Levenberg-Marquardt iteration
 
$$\sum_{r=1}^n \left\| \mathbf{K} \begin{bmatrix} \mathbf{R}_c \\ \mathbf{t}_c \end{bmatrix} \begin{bmatrix} {}^w\mathbf{R}_s \\ {}^w\mathbf{t}_s \end{bmatrix} \begin{bmatrix} \mathbf{X}_w \\ 1 \end{bmatrix} - \begin{bmatrix} x_r \\ 1 \end{bmatrix} \right\|^2$$
- Automatic computation of point correspondences by distance-weighted graph matching
- Automatic computation of the rigid transformation between the CT and tracking coordinate system using a dual quaternions approach

## Results

- Reconstruction error dependent on number of poses used for hand-eye calibration and hand-eye calibration method
- Real-time image undistortion and augmentation (15fps)
- Augmentation using our vision based registration method systematically outperforms a pointer based registration



## Conclusion

- Novel port placement method
  - without time-consuming prior manual segmentation of patient data
  - featuring a fast and accurate method for patient registration
- Easy to integrate into the current clinical workflow:
  - No need to touch patient with a robot or instrument during the registration process
  - Registration can be done by the surgical staff rather than the surgeon
- Positive feedback from cardiac surgeons on the use of the virtual fly-through for port placement
- Only one tracking system is needed, which may be an optical tracking system or a robot such as da Vinci

