Surgical Skill Evaluation in Endoscopic Sinus Surgery

Group 4

Vishwa Parekh

Mentors: Dr. Gregory Hager, Daniel Mirota, Narges Ahmidi

Outline

- Background
  - Minimally Invasive Surgical Procedure
  - Endoscopic Sinus Surgery
- Importance of good surgical skills in this procedure
- Goal of the Project
- Technical Approach
- Deliverables
- Dependencies
- Project Timeline
- Reading List

Minimally Invasive Surgery

- Less invasive than open surgery for the same purpose
- Use of laproscopic devices to access the surgical site.
- Indirect observation of the surgical site through an endoscope or a similar device

Advantages

- Reduces the operating time
- Reduces the time the patient requires to get back to their normal being.
- Prevents excessive loss of blood.

Endoscopic Sinus Surgery

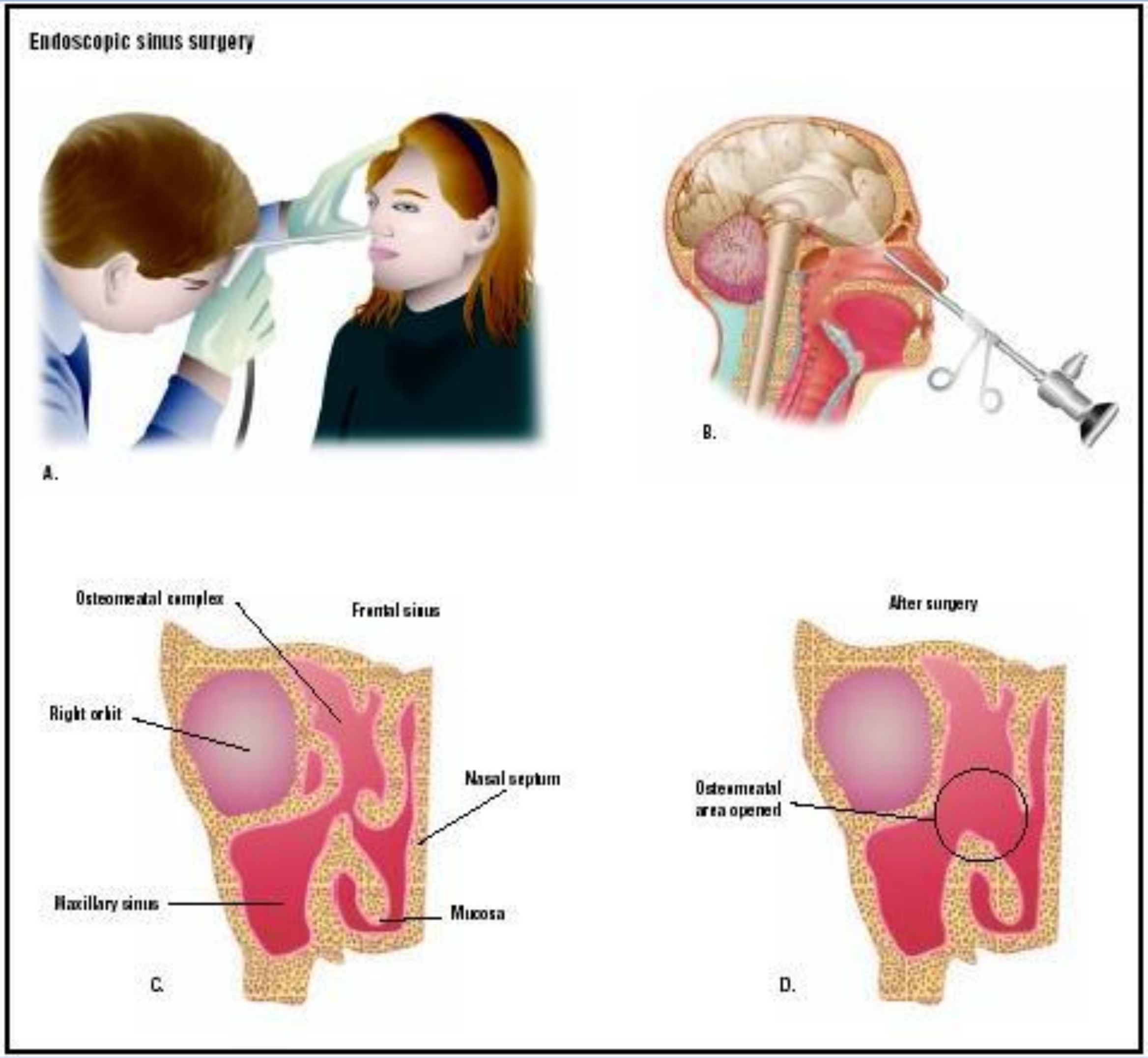


Illustration by GSS Inc.

Importance of good surgical skill in this procedure

- The sinus anatomy contains or is in vicinity of critical regions like carotid artery which supplies blood to the brain and optic nerve.
- Thus the surgical procedure involves a lot of critical movements which if not performed correctly can cause severe damage to the patient.

GOAL

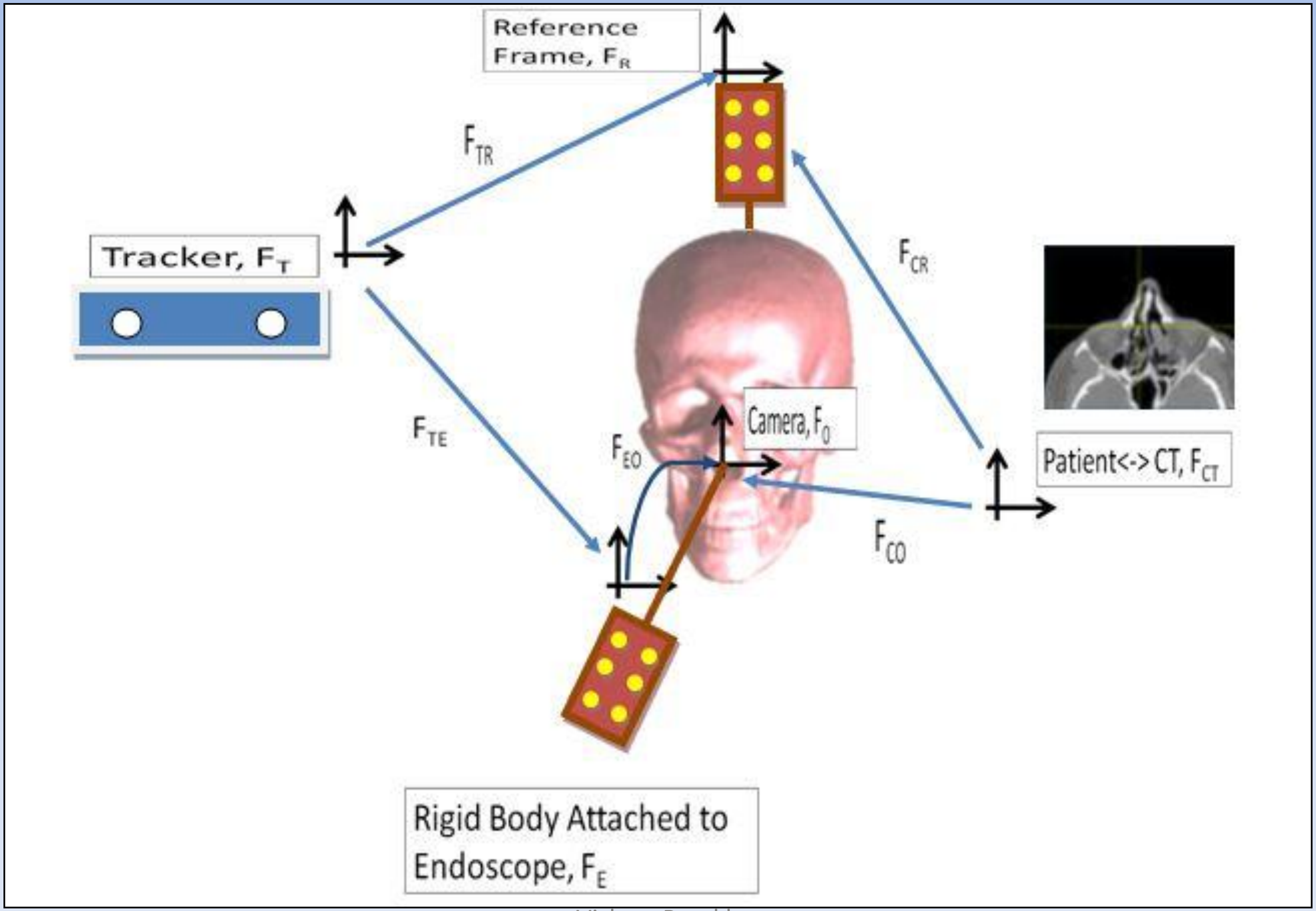
- Develop a mathematical model on surgical skill evaluation to identify and model the motion of critical movements to determine when these movements can lead to surgical complications.

Technical Approach

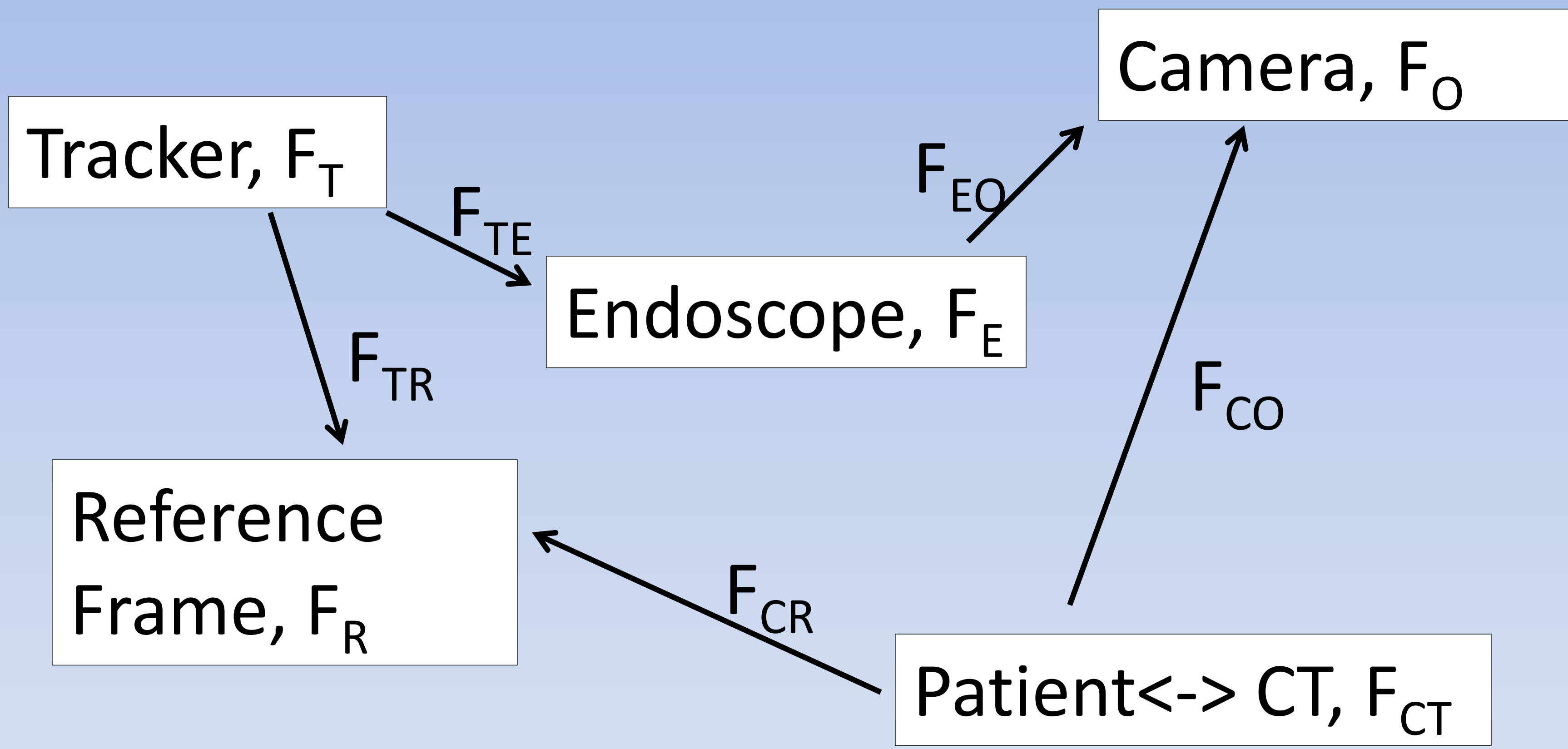
Record data from Surgery → Register camera motion to the patient CT → Model the different surgical movements from surgery

Repeat for multiple surgeons

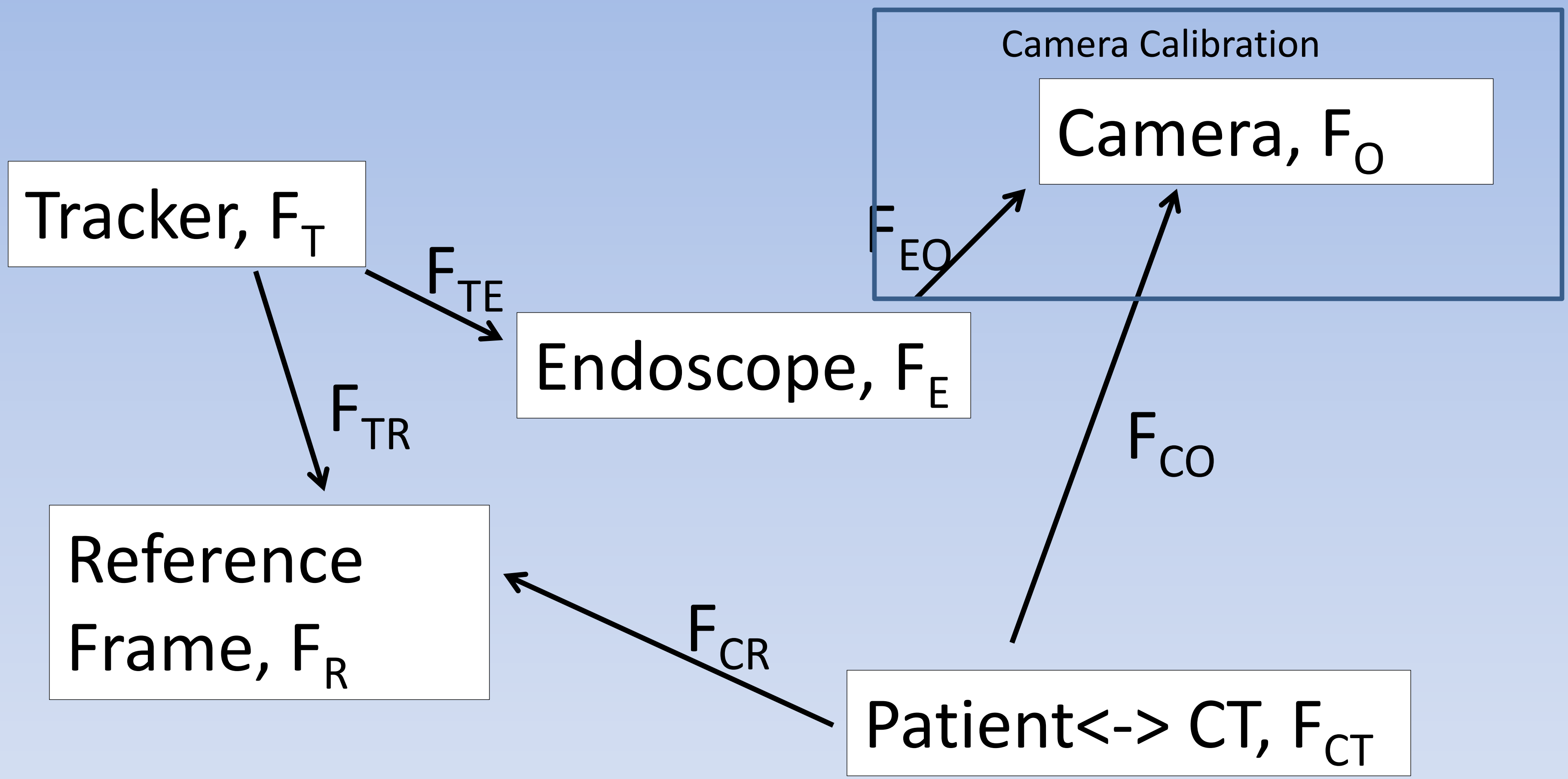
Diagrammatic representation of the system currently employed in the operating room



Block Diagram Representation of the System

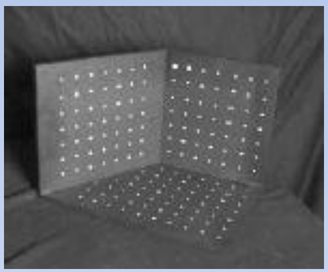


CAMERA CALIBRATION



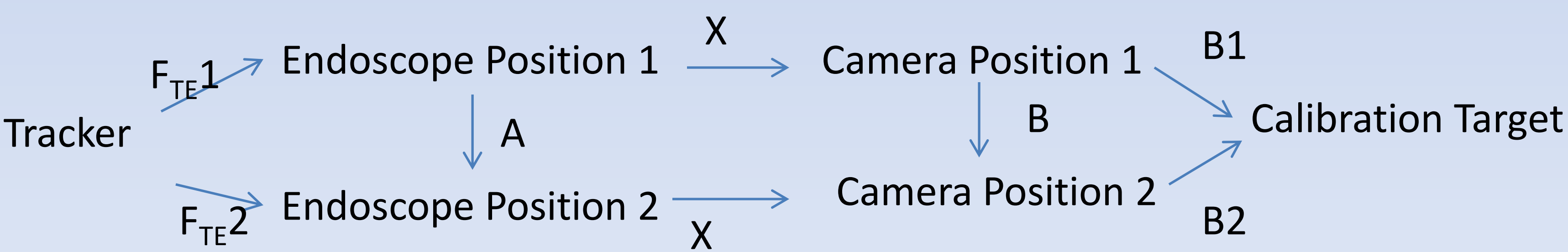
Camera Calibration

- Intrinsic Camera Parameters (focal length, principle point and lens distortion) and Extrinsic Camera Parameters (camera pose estimation) are found out using a 3D calibration target.

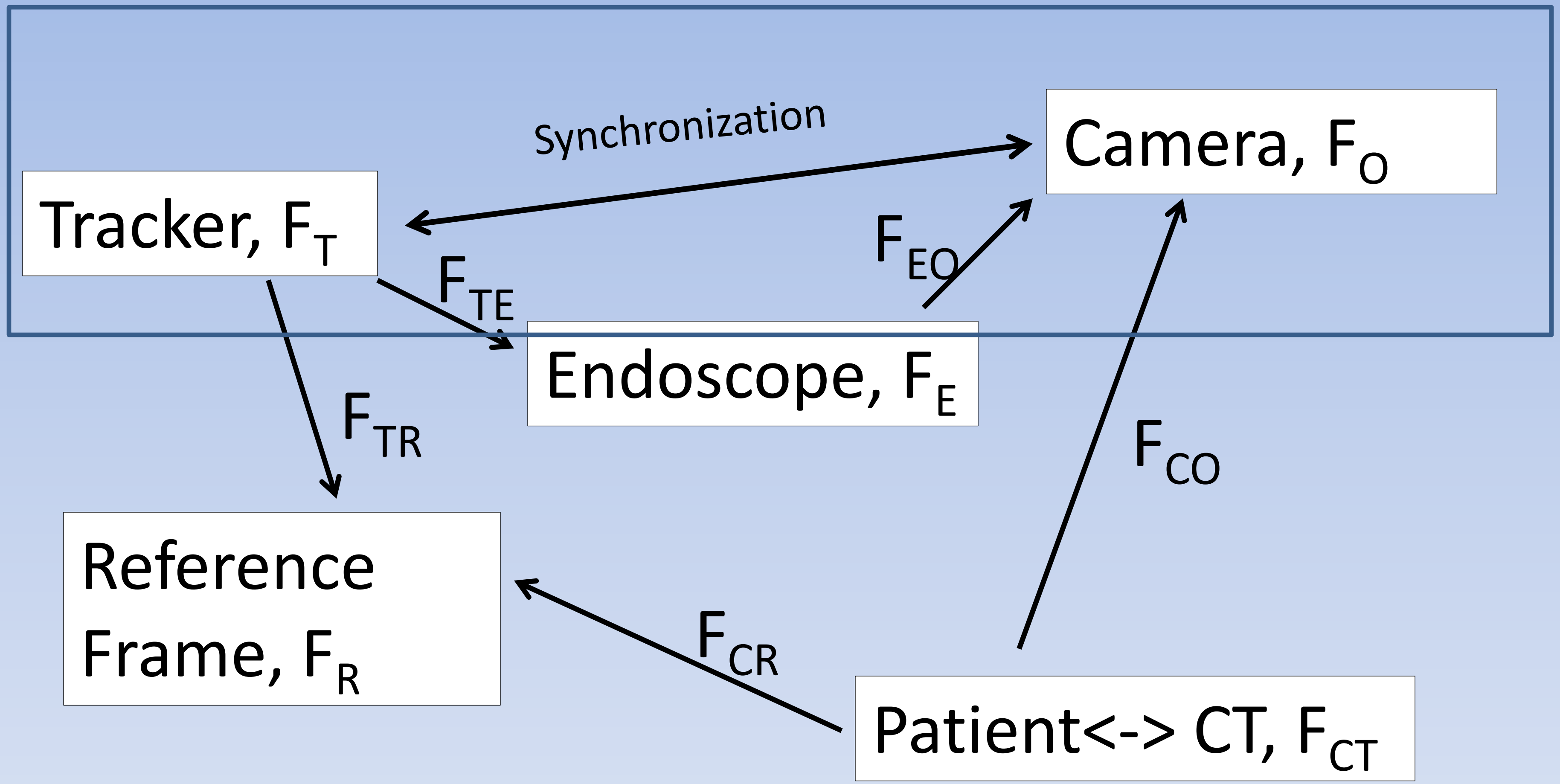


R.Y. Tsai, *An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision.* Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, Miami Beach, FL, pp. 364-374, 1986

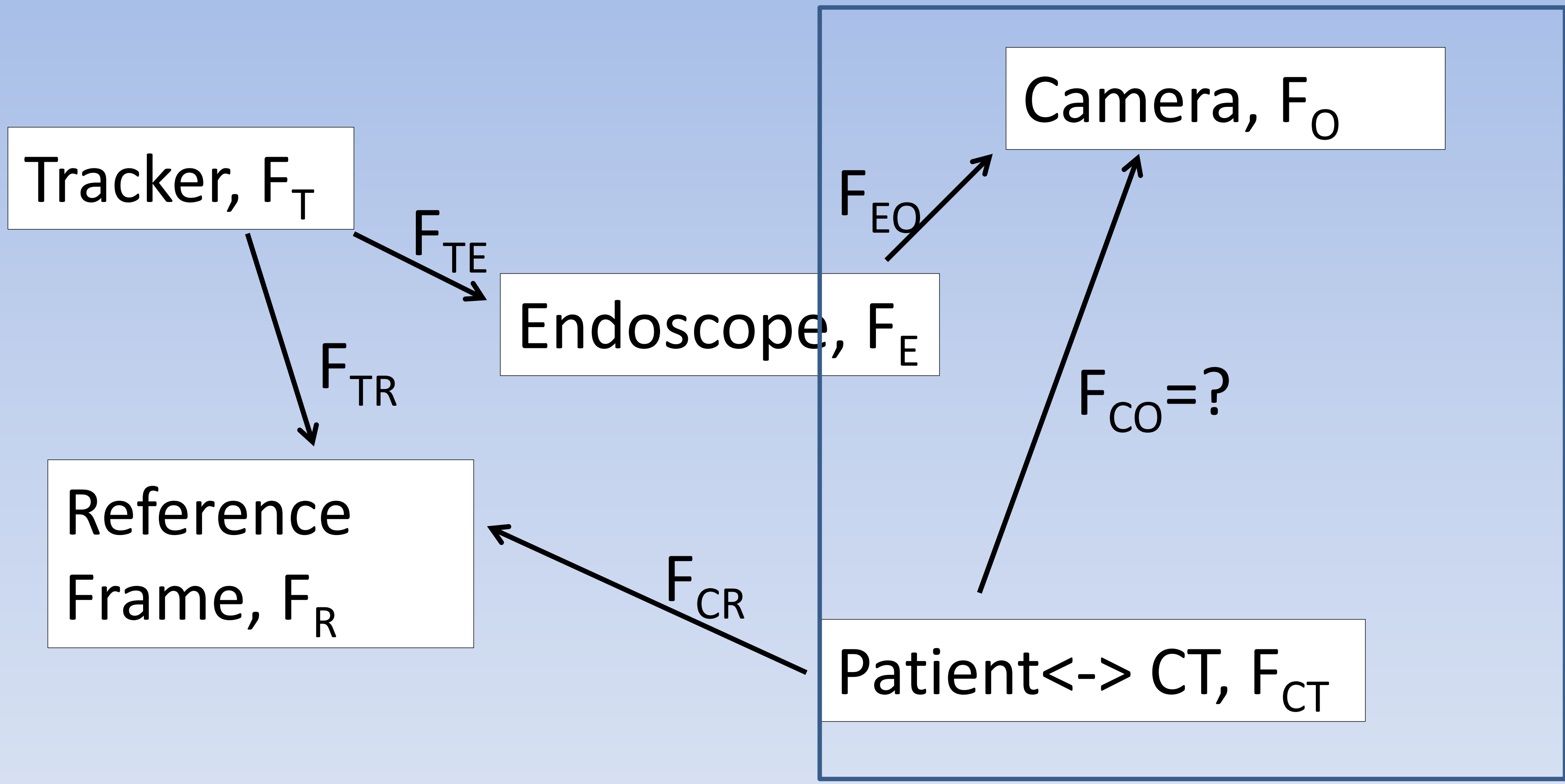
- Solving for F_{EO}:: AX =XB method from CIS1



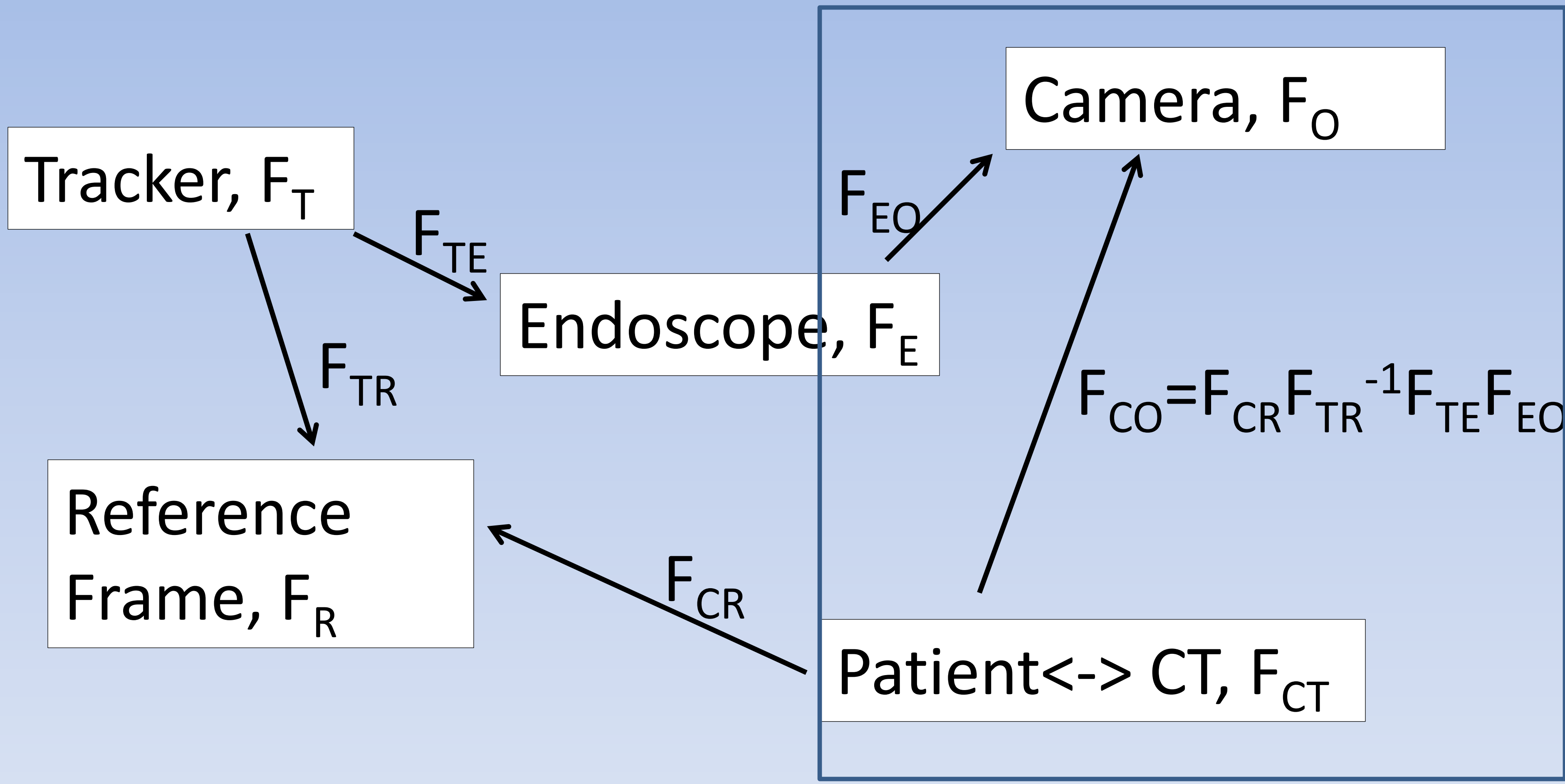
Synchronization



Camera-CT registration

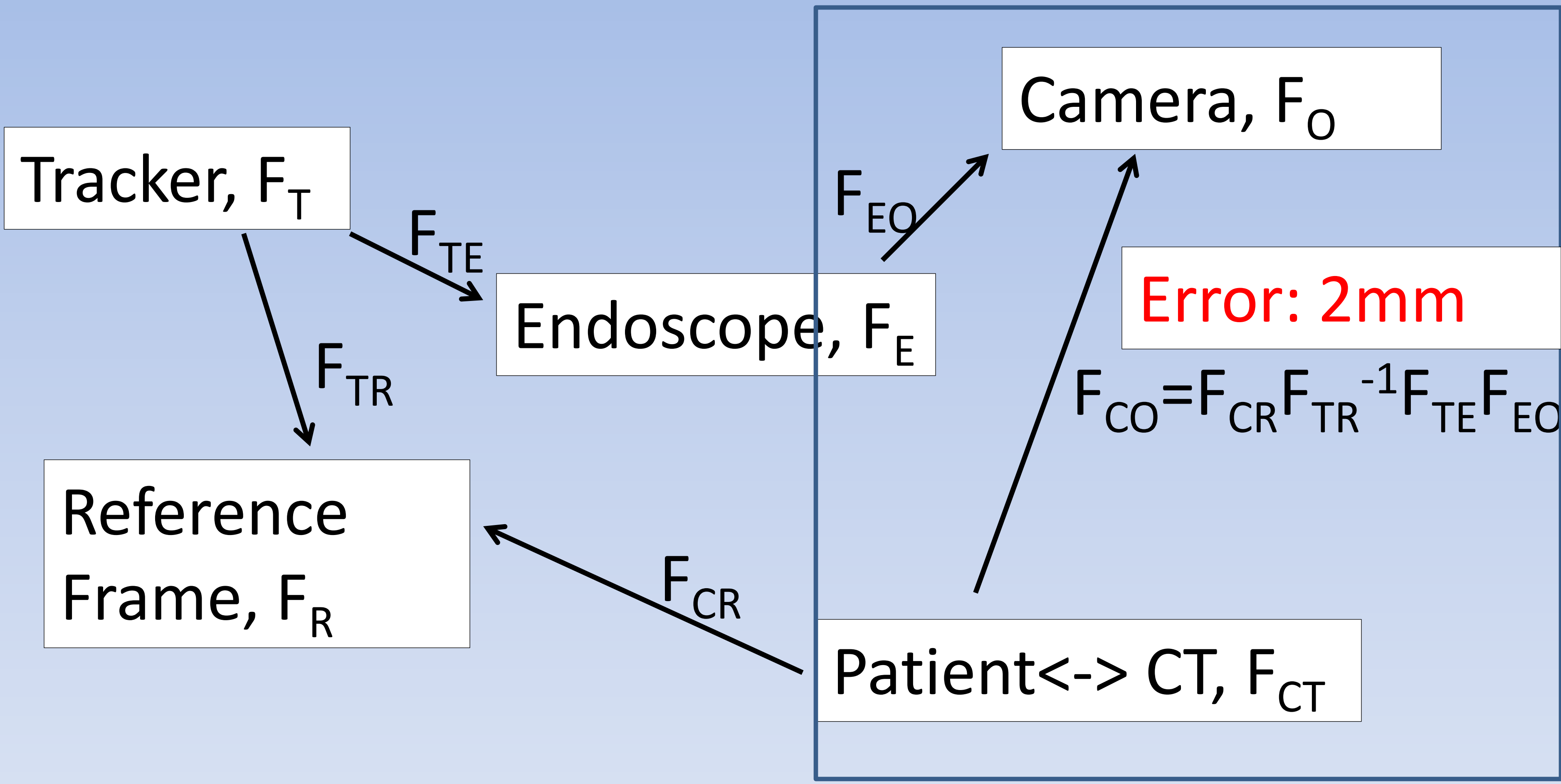


Camera-CT registration



Tracker Based Registration

Camera-CT registration



Tracker Based Registration

Camera-CT registration

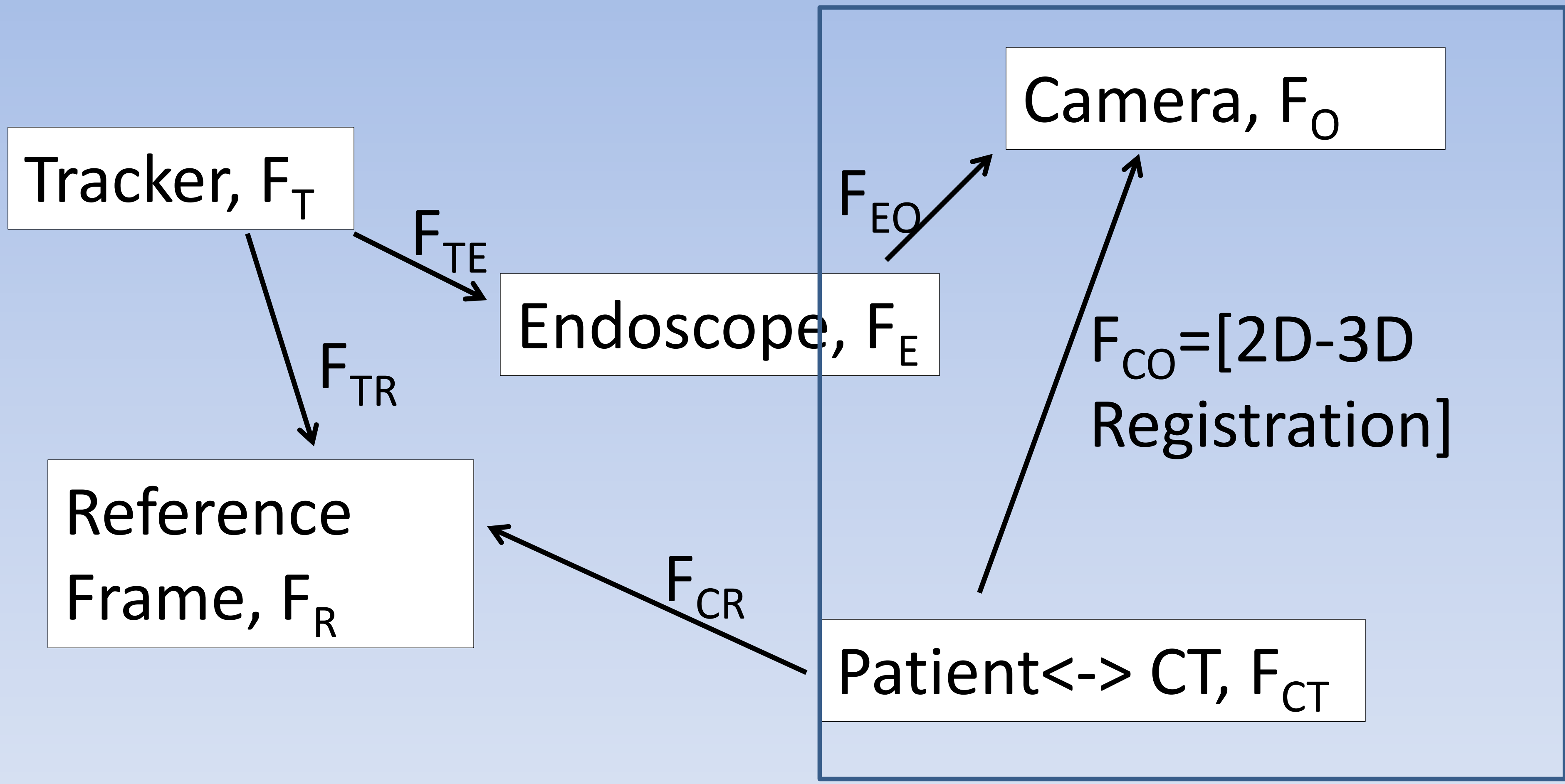


Image Based Registration

2D-3D registration

- Mark 6 non collinear landmarks on the image and on the CT
- P = 3 x 4 transformation matrix for the 3d points to image
- $p = [u,v,1]'$: points marked on image
- $q = [x,y,z,1]'$: 3D points on CT
- $p = Pq$
- $p \times Pq = 0$

Camera-CT registration

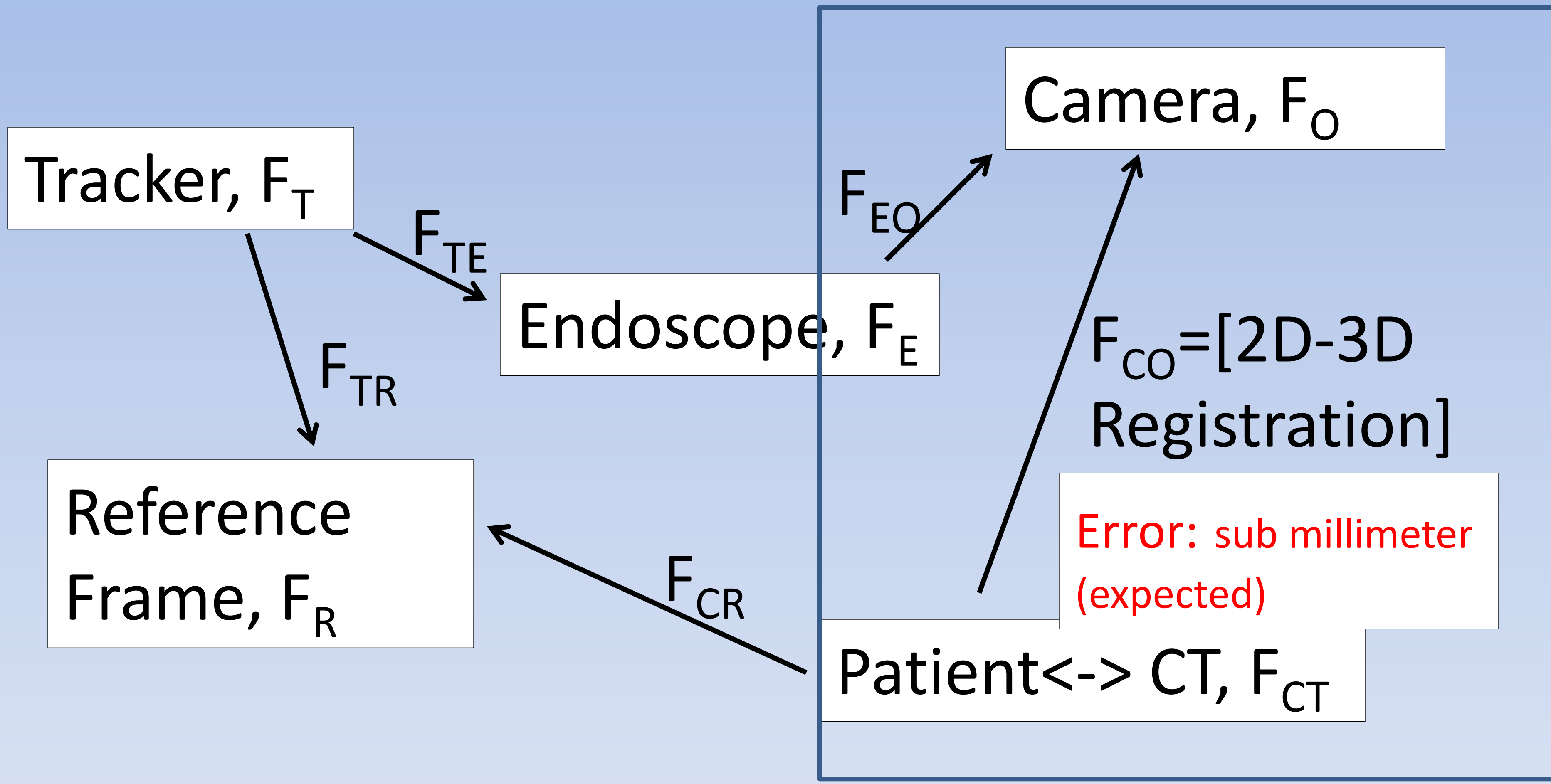
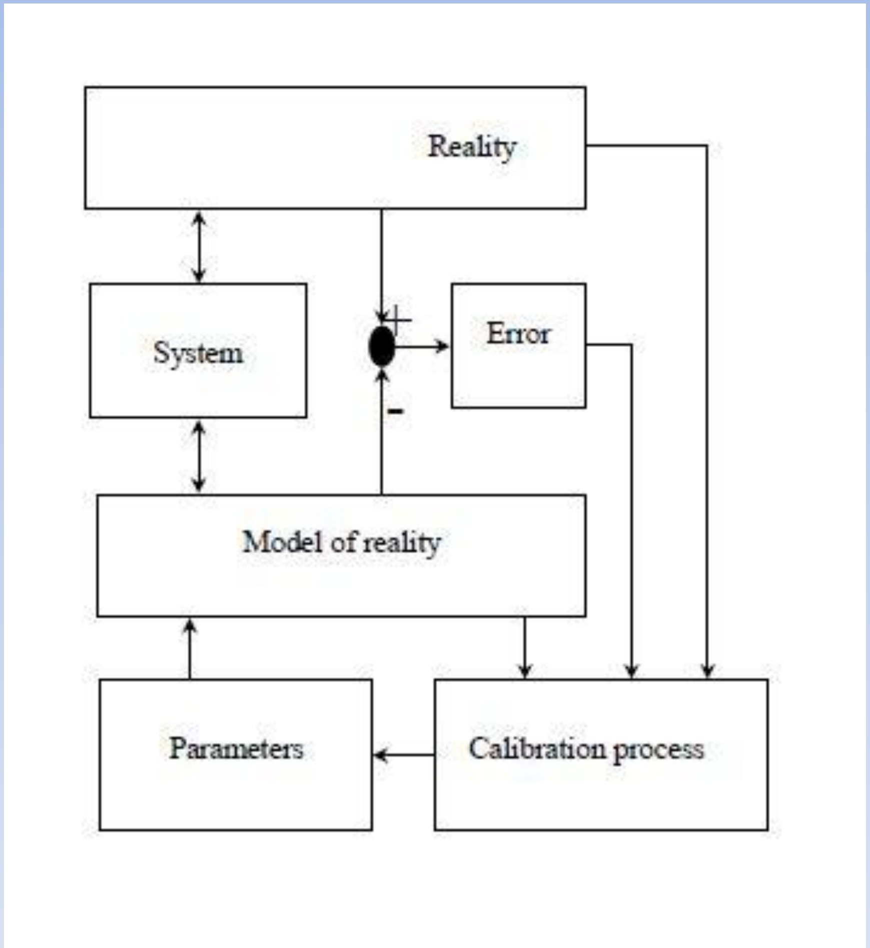


Image Based Registration

Optimize Registration over all frames of data

The result from tracker based registration produces a registration error of 2 mm while image based registration produces sub millimeter error, but is recorded only for a certain number of static frames. The aim of this step is to use the result from image based registration to optimize tracker based registration over all the frames. As shown in the figure we use calibration to calibrate tracker based registration to produce minimum error.



Cited: CIS1 slide 5 on calibration

Surgical Skill Modeling

- Segment the video frames into different movements (approach, handling the tool, etc.) for an expert conducted and a novice conducted surgery.
- Mathematically model these motions using a known technique (Hidden Markov Models).
- Differentiate between the critical movements between an expert and novice surgeon.

DELIVERABLES

Minimum:

- Develop software to Record Data from the surgery
- Develop software to compute the various transformations using the tracker data
- Develop a software to compute Registration between camera motion and CT data using Tracker based as well as Video based registration
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Expected:

- Minimum Deliverables
- Develop an algorithm to optimize registration over all frames and use it to optimize registration obtained using tracker based and video based registration.
- Model the different surgical movements for one surgeon.

Maximum:

- Expected Deliverables.
- Model the different surgical movements for multiple surgeons.
- Develop a model to classify a surgical movement into expert and novice category for different movements.

DEPENDENCIES

Dependency	Status	Plan for resolving
CISST Library	Resolved	-
Medtronic Stealthlink libraries	Resolved	-
System with capture card to record data from OR	Resolved	-
Training for Access to OR	Pending	Complete the training required for access to OR.
Required system (Stealthlink Tracker, endoscope, Foot pedal) in the OR	Pending	Mentors are working on to get this system into the OR
Software for Camera Calibration	Resolved	Part of CISST library.
Software for Surgical Modeling	Pending	Available in the lab. Talk to mentors for access.

Project Timeline

Task\Timeline	Feb 25	March 3	March 10	March 17	March 24	March 31	April 7	April 14	April 25	April 28	May 5	May 10
Software for Data Recording												
Code: Registration Preprocessing												
Test the software in Lab												
Record Data from OR												
Registration Software												
Optimization Software												
Surgical Skill Modeling for 1 surgeon												
Surgical Skill Modeling for 1 surgeon												

Management Plan

- Weekly meeting with mentor to discuss the progress of the project and review the milestones
- Work 15 hours every week

Reading List

- *D. J. Mirota, H. Wang, R. H. Taylor, M. Ishii, G. L. Gallia, and G. D. Hager, "A system for video-based navigation for endoscopic endonasal skull base surgery," medical imaging, IEEE transactions on, ISS. 99, 2011.*
- *Chien-ping Lu, Gregory D. Hager and Eric Mjolsness, 'fast and globally convergent pose estimation from video images', IEEE transactions on pattern analysis and machine intelligence, 2000*
- *Carol E. Reiley and Gregory D. Hager, 'Decomposition of Robotic Surgical Tasks: An analysis of Subtasks and Their Correlation to Skill.*
- D. J. Mirota, A. Uneri, S. Schafer, S. Nithiananthan, D. D. Reh, G. L. Gallia, R. H. Taylor, G. D. Hager, and J. H. Siewerdsen, "High-accuracy 3D image-based registration of endoscopic video to C-arm cone-beam CT for image-guided skull base surgery," in *Medical Imaging 2011: Visualization, Image-Guided Procedures, and Modeling*, 2011, p. 79640j-1.
- R.Y. Tsai, *An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision.* Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, Miami Beach, FL, pp. 364-374, 1986

Thank you…