# Evaluation of CT Registration for Image-based Sinus Reconstruction

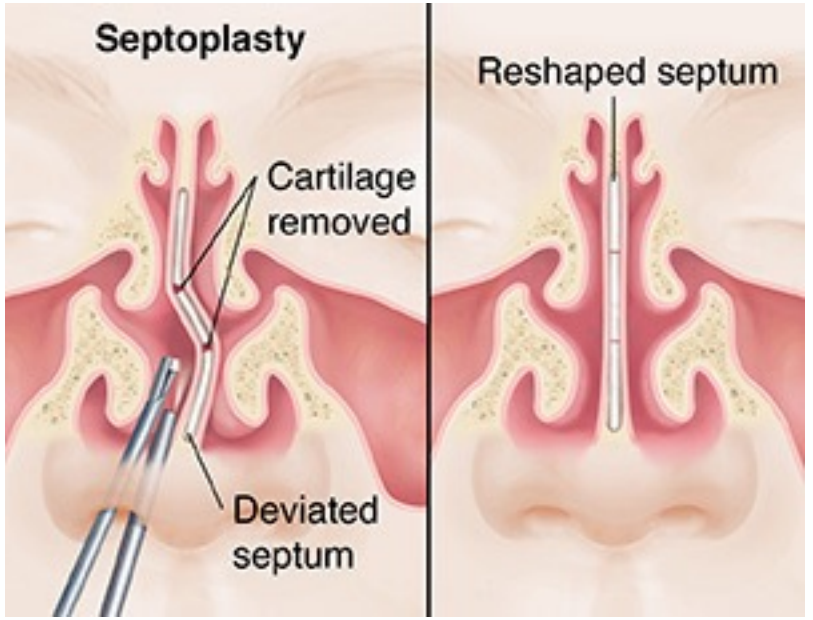
Jan Mangulabnan

Mentors: Dr. Roger Soberanis, Dr. Mathias Unberath

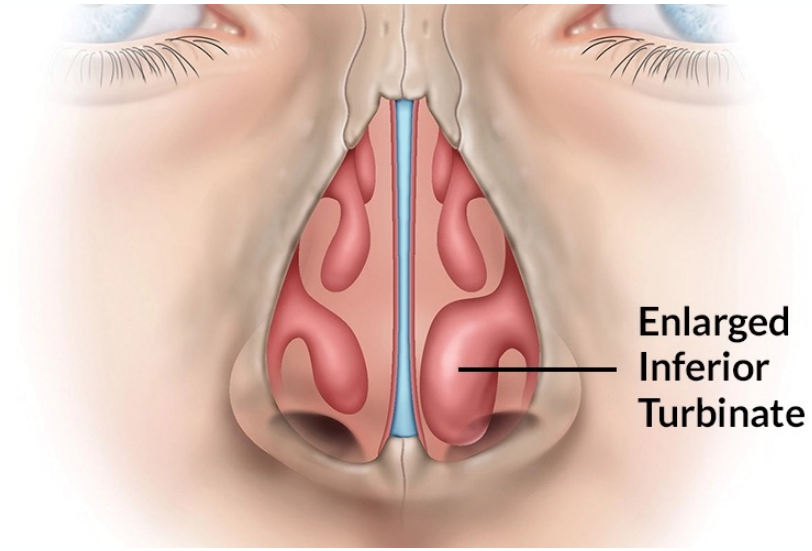
# Project Background

- Two most common surgeries for nasal obstructions
  - *Septoplasty*
  - *Turbinate Reduction*

- Inconclusive evidence towards surgical benefits of such surgeries [1]
- Studies mainly assess effectiveness based on subjective measures [2, 3]
  - *Self-reported patient questionnaires*



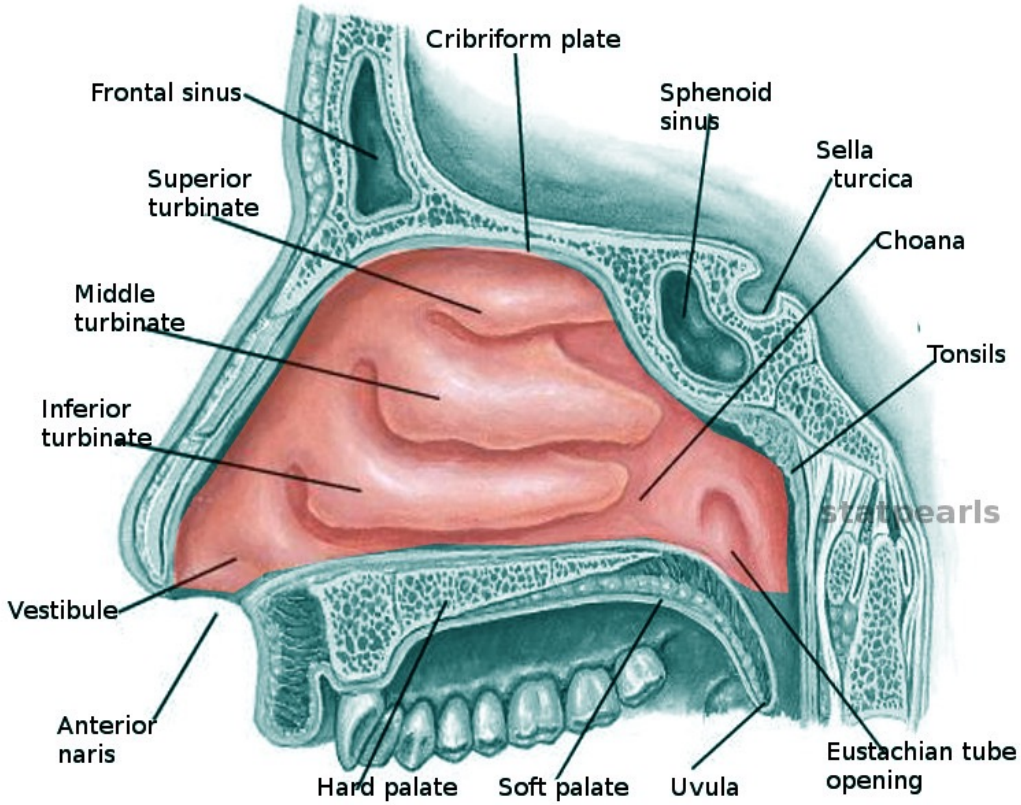

https://www.saintlukeskc.org/health-library/nasal-surgery-septoplasty




https://www.stlsinuscenter.com/common-sinus-problems/inferior-turbinate-hypertrophy/turbinate-reduction-surgery/

# Clinical Motivation

- Geometric information of patient anatomy
  - *Quantitative evaluation*
- CT scan for 3D structures
  - *High cost and ionizing radiation*
- Image-centered approach using routine endoscopy procedure
- 3D reconstructions must align with CT
  - *Measure clinically relevant parameters (ex. aperture and volume)*
- Allow for longitudinal assessment of surgical outcomes

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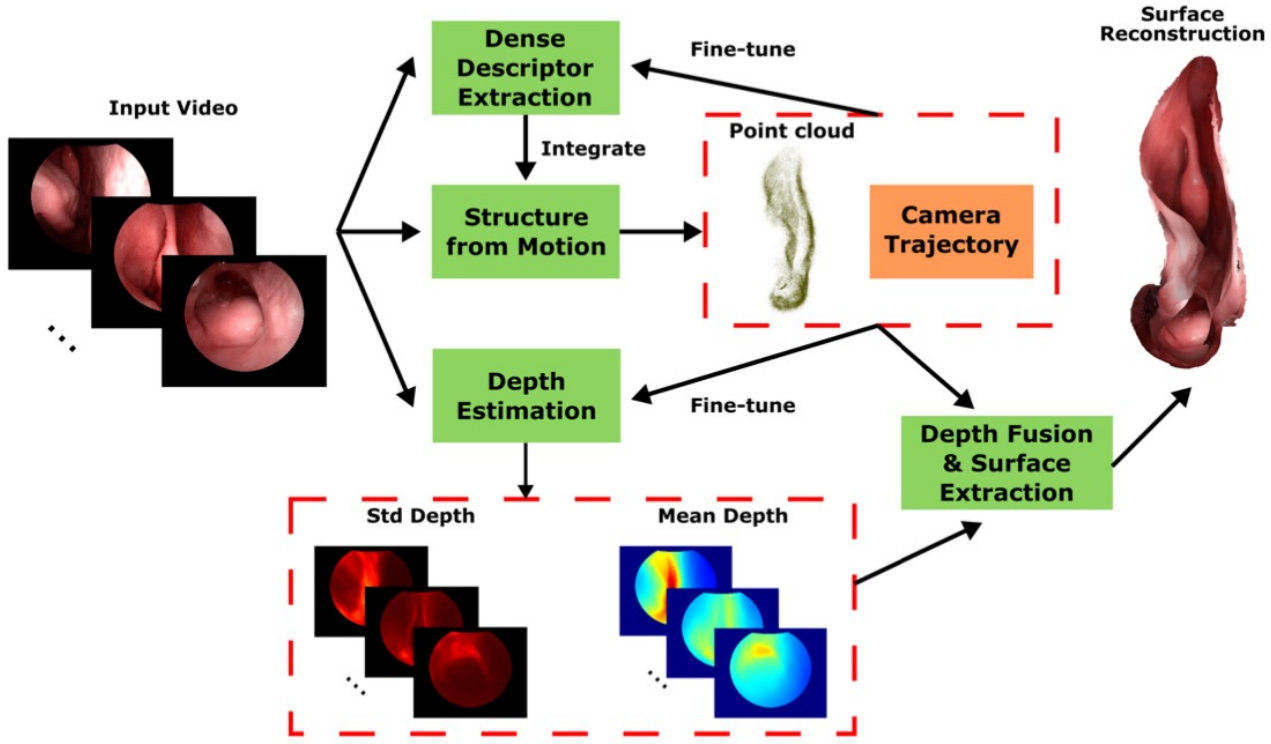
# **Prior Work:** Dense Reconstruction Pipeline

- Liu et. al developed a pipeline to reconstruct sinus anatomy from endoscopic video [4]
- Structure from Motion algorithm using a learning-based descriptor
  - *Outputs point cloud and camera trajectories*
- Point cloud and depth estimator used to produce 3D reconstruction



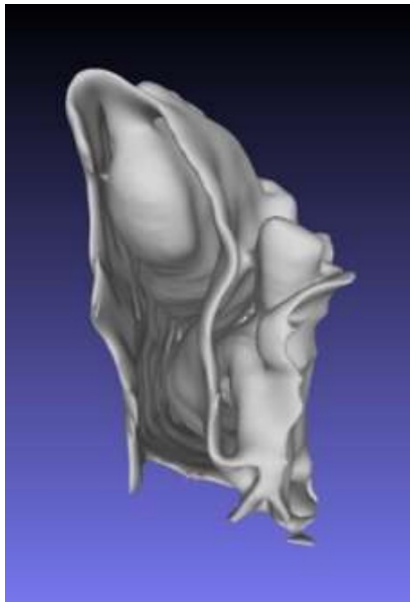

Liu, Xingtong, et al. "Reconstructing Sinus Anatomy from Endoscopic Video -- Towards a Radiation-Free Approach for Quantitative Longitudinal Assessment" Medical Image Computing and Computer Assisted Intervention (2020)

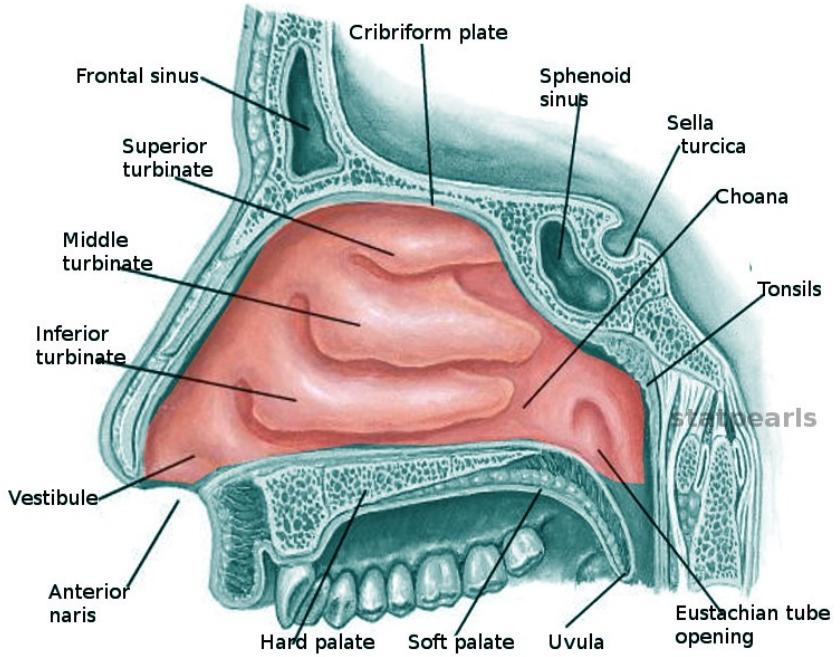
# GOAL:

Implement a quantitative framework to evaluate registration between image-based 3D reconstruction of the sinus anatomy and their corresponding CT image

# Technical Approach

1. Integrate rigid registration methods (ICP, IMLP[1] and variations [4]) with 3D reconstruction and CT scan
2. Use entire 3D reconstruction to apply global registration to CT scan
3. Implement and report evaluation metrics and visualization
4. Isolate anatomical regions of interest in video sequence and generate corresponding 3D reconstructions
5. Use 3D reconstruction of isolated anatomy to apply local registration
6. Report evaluation



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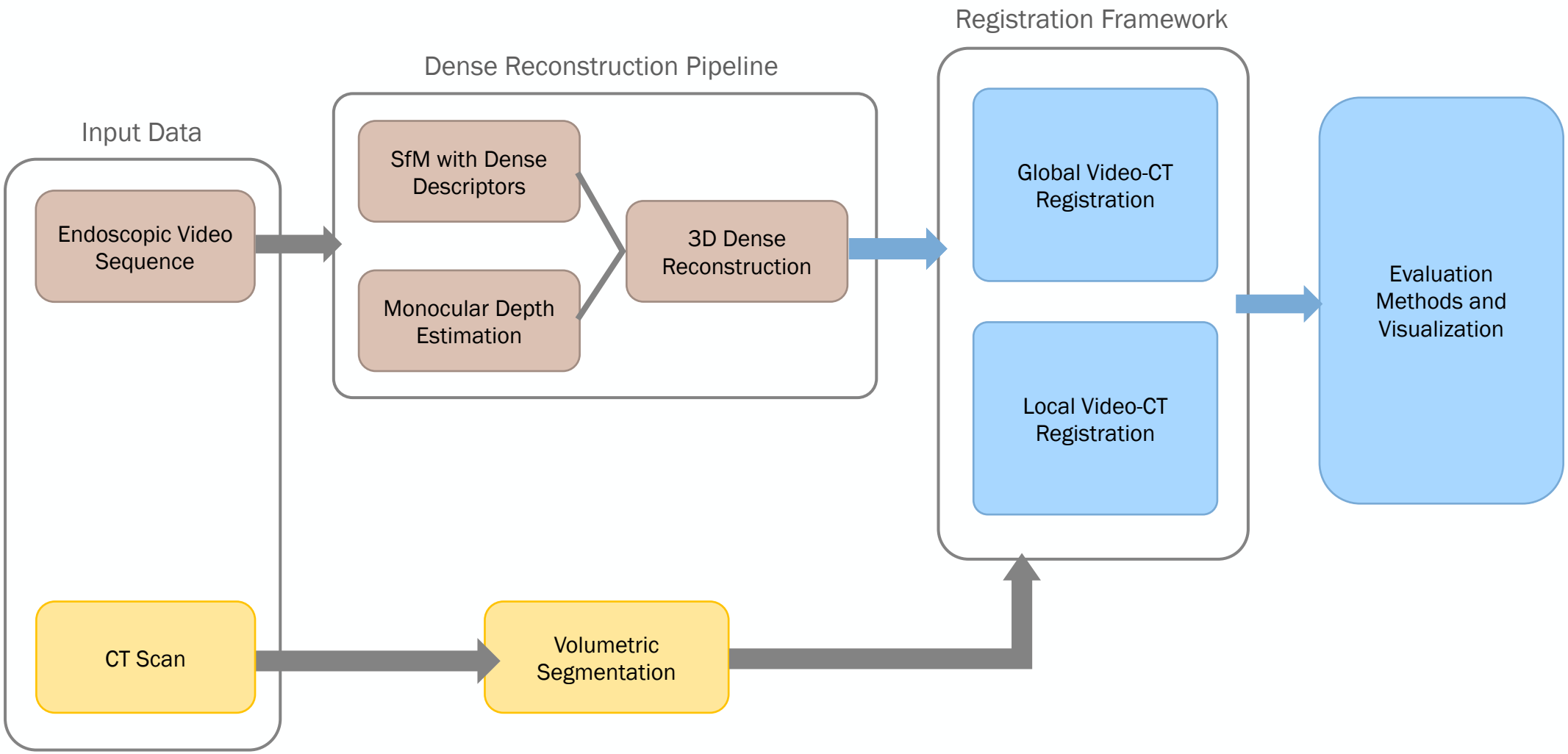
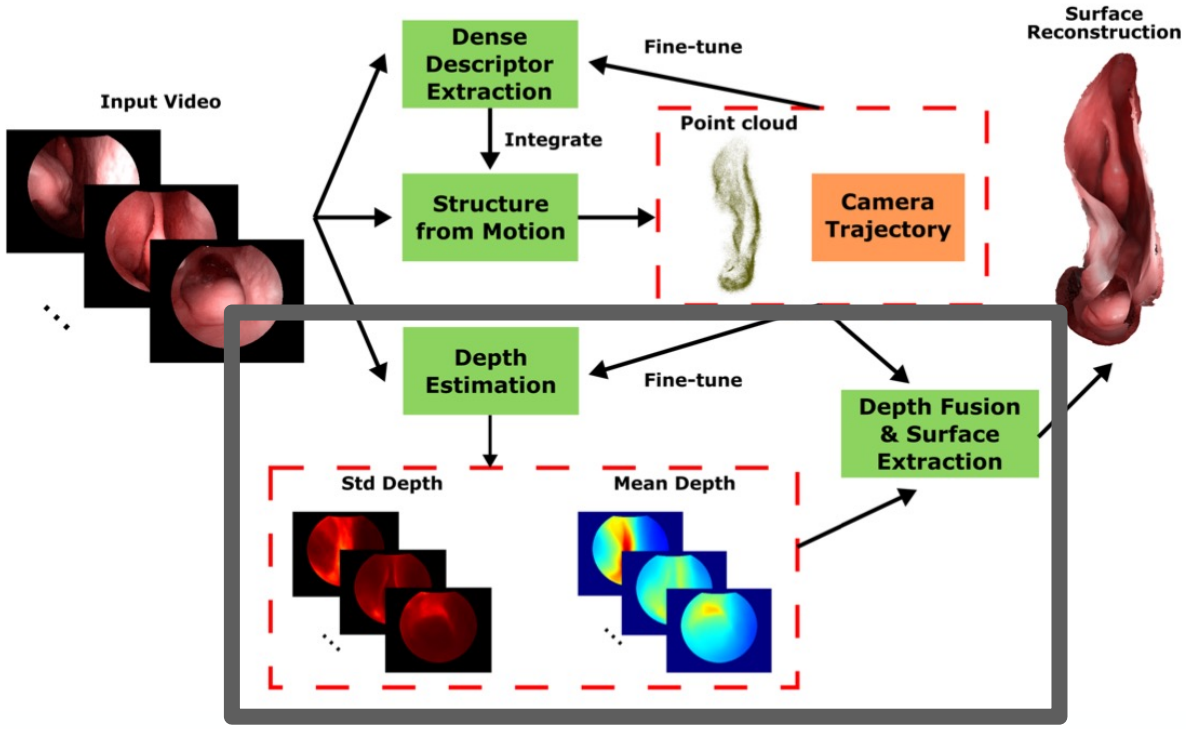
[1]https://github.com/AyushiSinha/cisstICP

# Technical Approach



# Technical Approach

- Deep-learning based depth estimator [5] is utilized in 3D reconstruction using fusion method [6]
- Resolves noise in depth estimates
  - *Considers all estimates equally*
- Analyze uncertainties in depth estimation
  - *Suspect that points further from the camera may introduce error*
- Integrate probabilistic model
  - *Account for potential errors in depth estimation*

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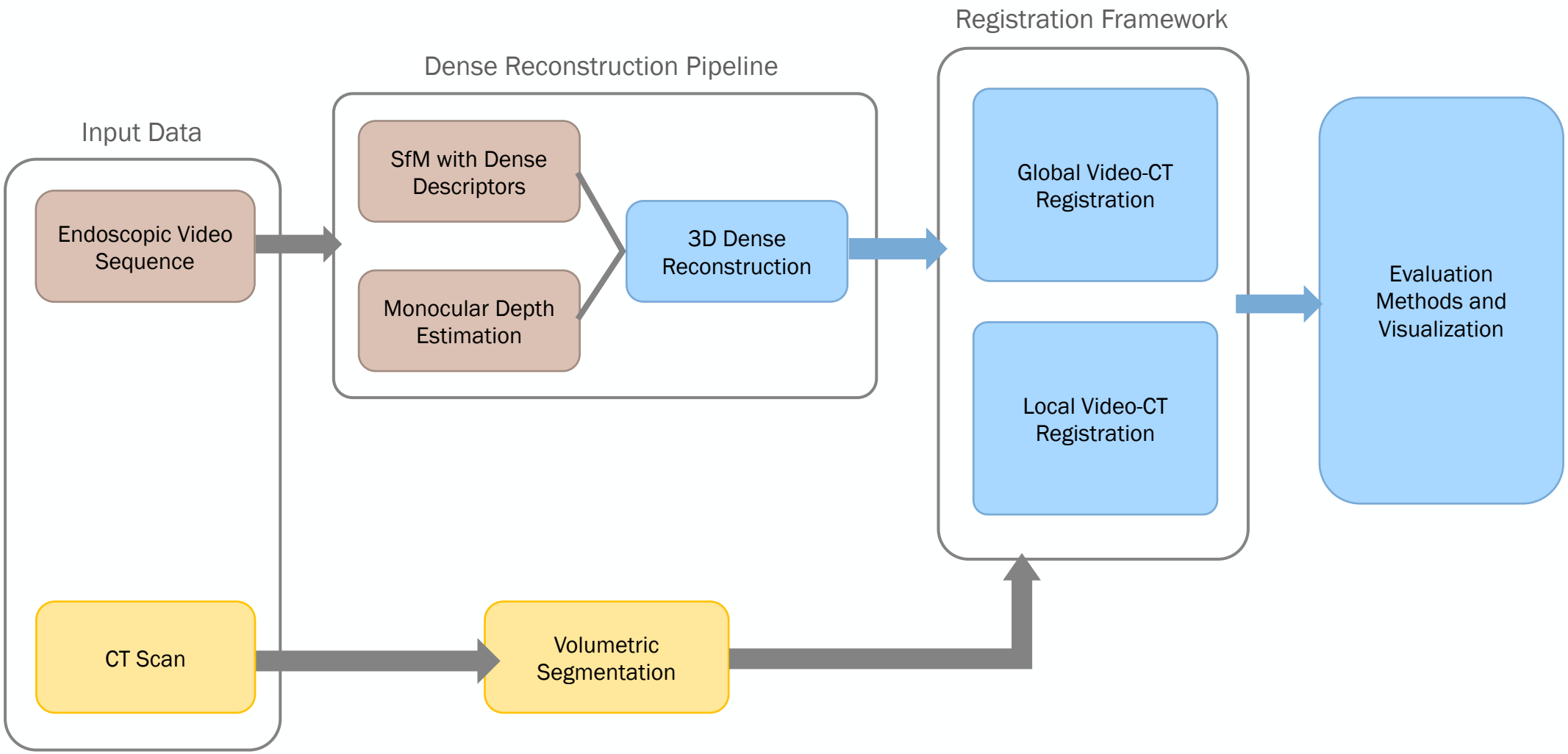
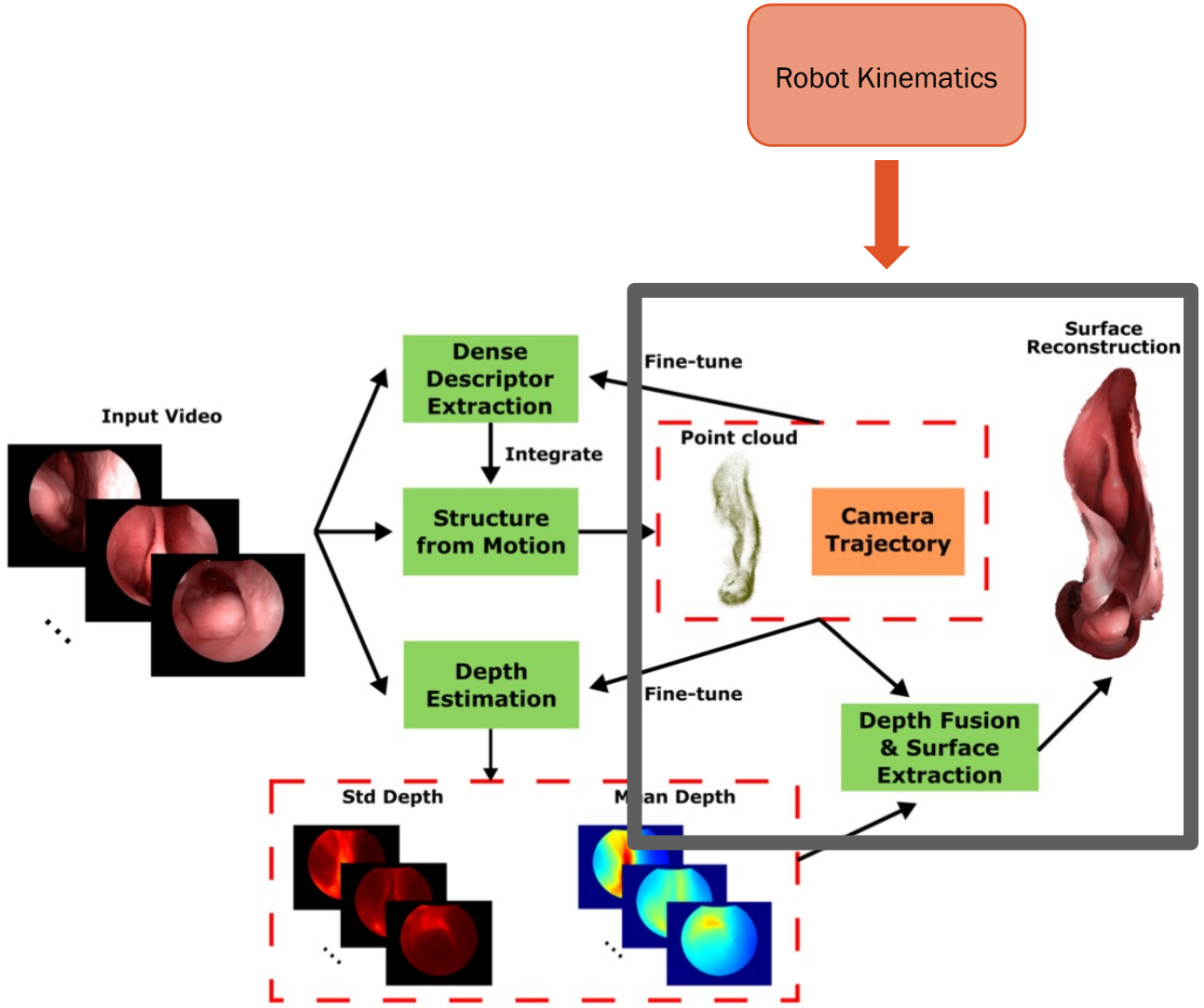
# Technical Approach

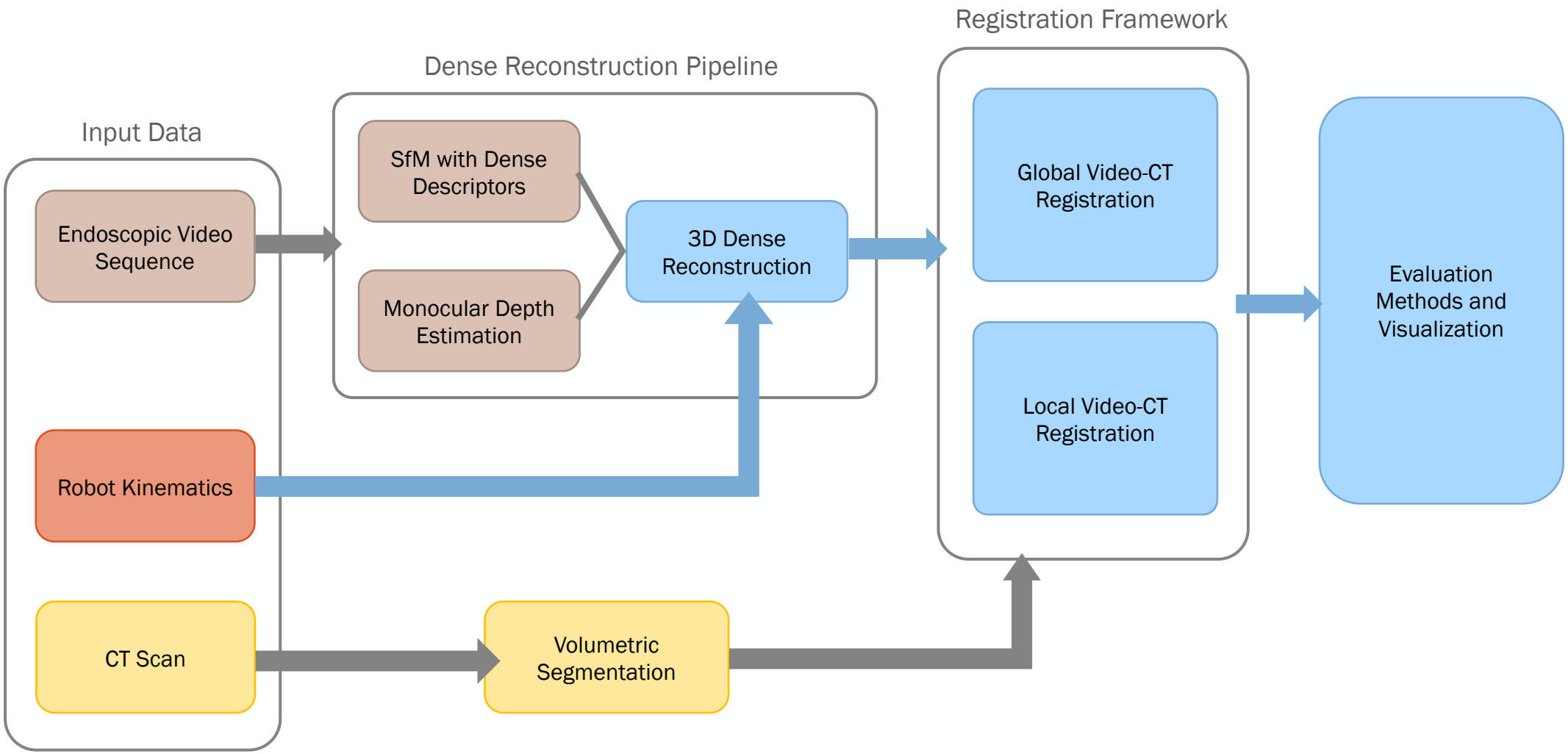


# Technical Approach

- Robot kinematic data corresponds to endoscopic video sequence
- Provides information related to the location of the endoscope
- Integrate into reconstruction process to improve camera trajectory
  - *Input into depth fusion*
- Produce local and global 3D reconstructions and evaluate



# Technical Approach



# Key Deliverables

| | Activities | Deliverables |
|---|---|---|
| Expected | Data pre-processing: generate dense reconstructions and perform CT segmentation | 3D Dense Reconstruction and Segmented CT scans |
| | Integrate rigid registration methods (ICP, IMLP and variations) for global registration | Code and documentation |
| | Implement data processing steps to isolate local regions and apply rigid registration methods | Code and documentation |
| | Report error evaluation between dense reco and CT ground truth with visualizations | Report of evaluated data |
| Minimum | Adjust depth fusion step in pipeline to account for uncertainties in estimation | Code and documentation |
| | Evaluation of new dense reconstruction | Resulting dense reconstruction and comparison report |
| Maximum | Integrate robot kinematics into registration method | Code and documentation |
| | Evaluation of new dense reconstruction | Resulting dense reconstruction and comparison report |

# Dependencies

| Dependency | Need | Status | Follow-up | Contingency Plan |
|---|---|---|---|---|
| Computing Power | Run dense reco pipeline | Ready to use | ARCADE lab workstation | N/A |
| Dense Reconstruction Pipeline | Generate 3D sinus reconstructions | Ready to use | N/A | Available on github |
| cisstICP Library | Implementation of registration methods | Installed | N/A | Available on github |
| 3D Slicer | Segment CT scans | Installed | N/A | N/A |
| Sinus Data | Input for dense reconstruction pipeline | Available | N/A | Additional cadaveric data collection sessions |
| CT scans | Ground truth | Available | N/A | Additional cadaveric data collection sessions |
| Robot kinematic data | Integration into reconstruction pipeline | Located | Obtain from Manish | Additional cadaveric data collection sessions |

# Project Timeline & Milestones

| Milestones | February | | | | March | | | | April | | | | May | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 13 | 20 | 27 | 6 | 13 | 20 | 27 | 3 | 10 | 17 | 24 | 1 | 8 |
| 1. Setup and Data Pre-processing | | | | | | | | | | | | | | |
| 1.1 Project Proposal | | | | | | | | | | | | | | |
| 1.2 cisstICP Setup | | | | | | | | | | | | | | |
| 1.3 Generate 3D Reconstructions | | | | | | | | | | | | | | |
| 1.4 Segment CT Scans | | | | | | | | | | | | | | |
| 2. Implementation | | | | | | | | | | | | | | |
| 2.1 Global Registration | | | | | | | | | | | | | | |
| 2.2 Isolate anatomical regions of interest | | | | | | | | | | | | | | |
| 2.3 Local Registration | | | | | | | | | | | | | | |
| 2.4 Evaluation Metrics and Visualization | | | | | | | | | | | | | | |
| 3. Influence of Uncertainties | | | | | | | | | | | | | | |
| 3.1 Analyze distribution of depth estimation | | | | | | | | | | | | | | |
| 3.2 Adjust for uncertainties in depth fusion | | | | | | | | | | | | | | |
| 3.3 Report Evaluation Metrics and Visualization | | | | | | | | | | | | | | |
| 4. Robot Kinematics | | | | | | | | | | | | | | |
| 4.1 Integrate robotic data into registration | | | | | | | | | | | | | | |
| 4.2 Report Evaluation Metrics and Visualization | | | | | | | | | | | | | | |
| 5. Writing | | | | | | | | | | | | | | |
| 5.1 Finalize code and documentation | | | | | | | | | | | | | | |
| 5.2 Prepare final report | | | | | | | | | | | | | | |

# Roles and Responsibilities

Team:

**Jan Mangulabnan**
*PhD Student*

**Timo Teufel** – assist with data pre-processing
*Visiting Graduate Student in ARCADE Lab*

Mentors:

**Roger Soberanis**, *PhD*
*Postdoc in ARCADE Lab*

**Mathias Unberath**, *PhD*
*Assistant Professor in Computer Science*

# Management Plan

- Weekly meetings with Roger
- Bi-weekly meetings with Mathias
- Weekly lab meetings: progress reports

Communication

- Slack / Email

Management

- Private github repository
- Google Drive

# References

[1] Roblin, D., Eccles, R.: What, if any, is the value of septal surgery? Clinical Otolaryngology & Allied Sciences 27(2), 77–80 (2002)

[2] Lavinsky-Wolff, M., Camargo Jr, H.L., Barone, C.R., Rabaioli, L., Wolff, F.H., Dolci, J.E.L., Polanczyk, C.A.: Effect of turbinate surgery in rhinoseptoplasty on quality-of-life and acoustic rhinometry outcomes: a randomized clinical trial. The Laryngoscope 123(1), 82–89 (2013)

[3] Hytonen, M.L., Lilja, M., Makitie, A.A., Sintonen, H., Roine, R.P.: Does septoplasty enhance the quality of life in patients? European archives of oto-rhino-laryngology 269, 2497–2503 (2012)

[4] Liu, X., Stiber, M., Huang, J., Ishii, M., Hager, G.D., Taylor, R.H., Unberath, M.: Reconstructing sinus anatomy from endoscopic video – towards a radiation-free approach for quantitative longitudinal assessment. In: Martel, A.L., Abolmaesumi, P., Stoyanov, D., Mateus, D., Zuluaga, M.A., Zhou, S.K., Racoceanu, D., Joskowicz, L. (eds.) Medical Image Computing and Computer Assisted Intervention – MICCAI 2020, pp. 3–13. Springer, Cham (2020)

[5] Sinha, A., Billings, S.D., Reiter, A., Liu, X., Ishii, M., Hager, G.D., Taylor, R.H.: The deformable most-likely-point paradigm. Medical image analysis 55, 148–164 (2019)

[6] Liu, X., Sinha, A., Ishii, M., Hager, G.D., Reiter, A., Taylor, R.H., Unberath, M.: Dense depth estimation in monocular endoscopy with self- supervised learning methods. IEEE transactions on medical imaging 39(5), 1438–1447 (2019)

[7] Curless, B., Levoy, M.: A volumetric method for building complex models from range images. In: Proceedings of the 23rd Annual Conference on Computer Graphics and Interactive Techniques, pp. 303–312 (1996)