A REAL-TIME IMAGE STITCHING FRAMEWORK FOR FETOSCOPIC FIELD-OF-VIEW EXPANSION

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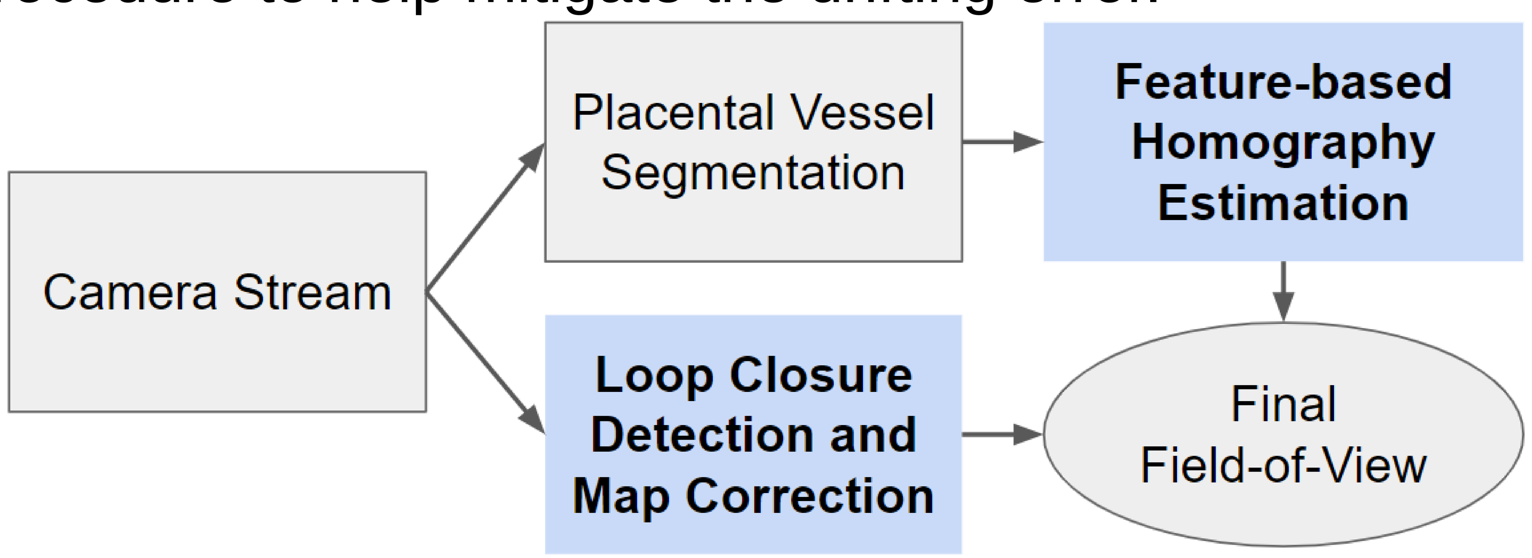
Introduction

- Treatment of twin-to-twin transfusion syndrome (TTTS) can be hindered by a limited fetoscopic field-of-view, a challenge that can be addressed through image stitching.
- A state-of-the-art framework incorporates **U-Net based segmentation of placental vessels** for more consistent frame-to-frame image registration [1].
- While accurate, this method has not demonstrated **real-time capabilities** [2] where images can be stitched at 10 Hz.

Objectives

- Achieve faster image stitching through a **feature-based (SIFT) homography estimation** from the segmented placental vessel maps.
- Implement a simple **loop closure-based map correction** procedure to help mitigate the drifting error.



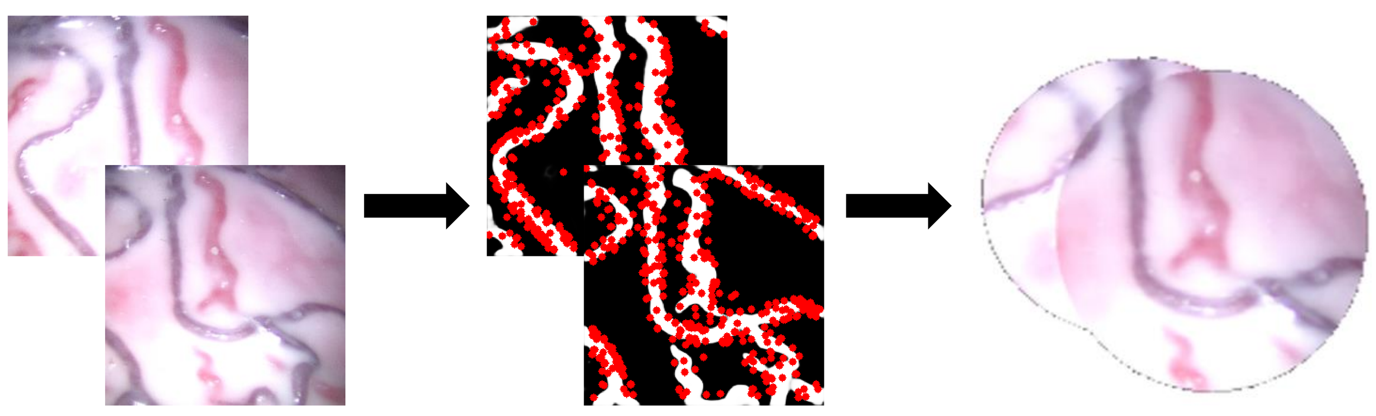
Methodology

Vessel Segmentation:

- **Training data:** Six *in vivo* endoscopic videos and the corresponding annotations [1], and custom data obtained from a phantom placenta and annotated manually.
- **U-Net Architecture:** ResNet-101 backbone pre-trained with ImageNet weights.

Field-of-view Expansion:

- **Homography Estimation:** Features obtained from the segmented frames (SIFT), an optical flow is calculated (Lucas-Kanade), and outliers are removed (RANSAC).
- **Image Stitching:** Circular masks are applied to the rectangular frames to enhance lighting consistency.

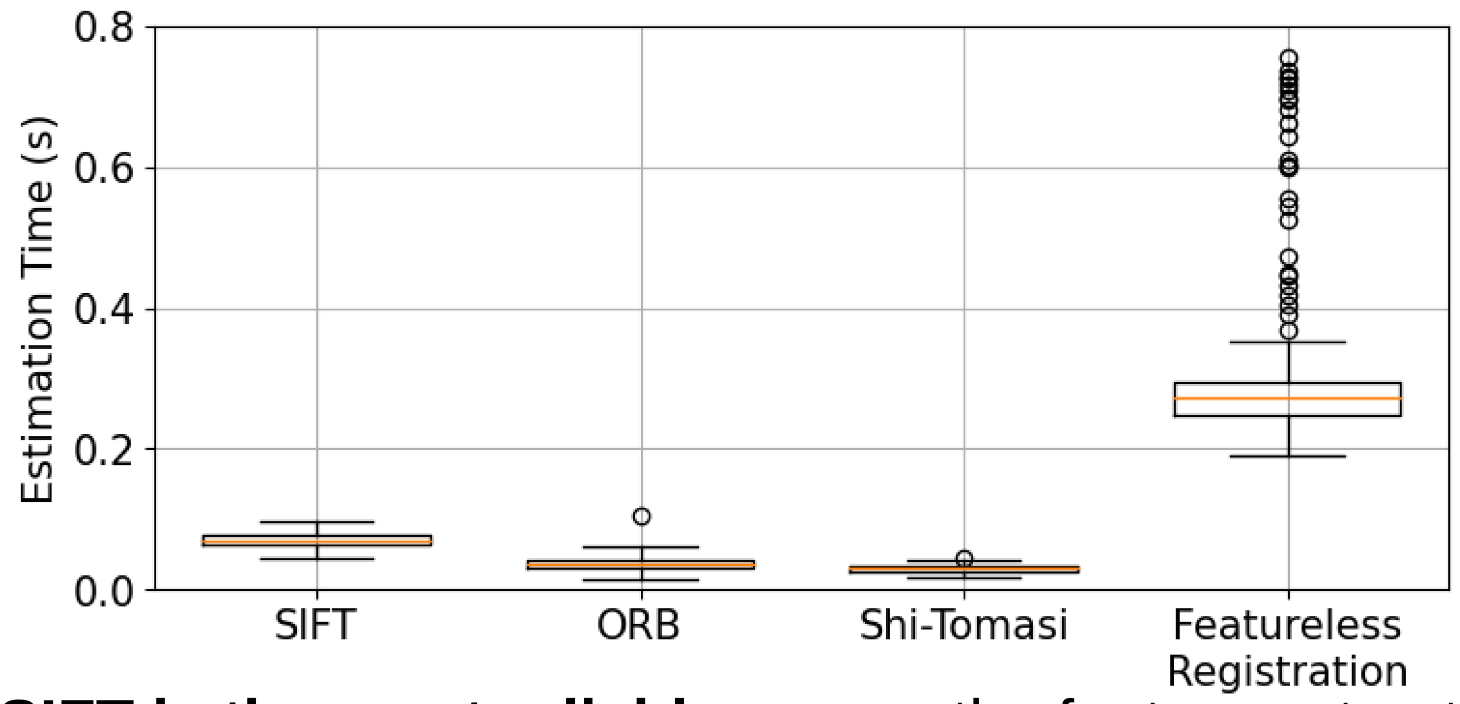


Addressing Drifting Errors:

- **Loop Closure Detection:** A histogram is generated for each frame by clustering its SIFT descriptors. A loop is detected when the Wasserstein distance between a given and initial histogram falls below a threshold.
- **Map Correction:** Once a loop closure is detected, the overlapping initial and final frames of the loop are restitched and all other homographies are adjusted.

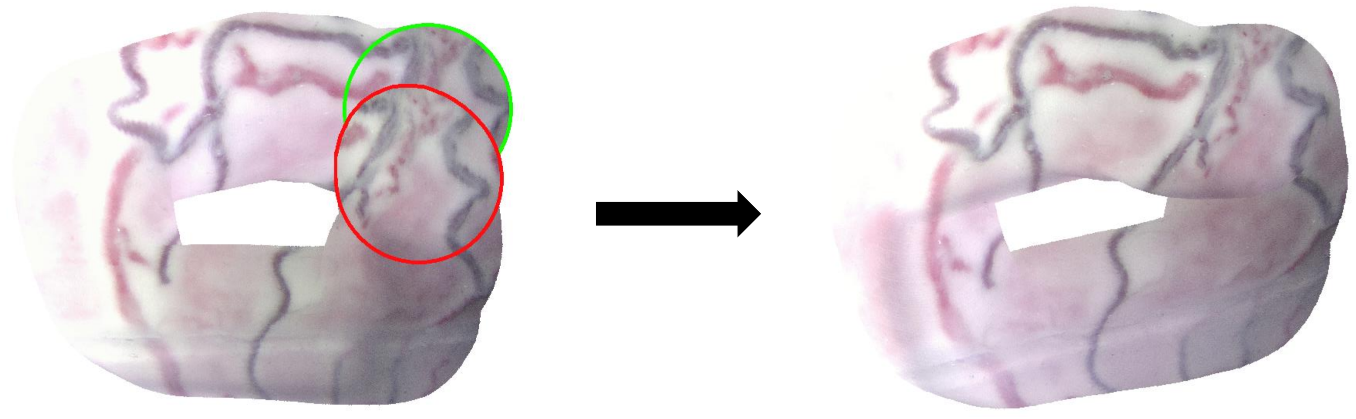
Results

Frame-to-frame estimation times across various feature extractors and a featureless iterative registration method:



- **SIFT is the most reliable** among the feature extractors while upholding real-time performance.
- Reliability analysis involved error measurements across **scaling, translation, and rotation** of the camera frame.

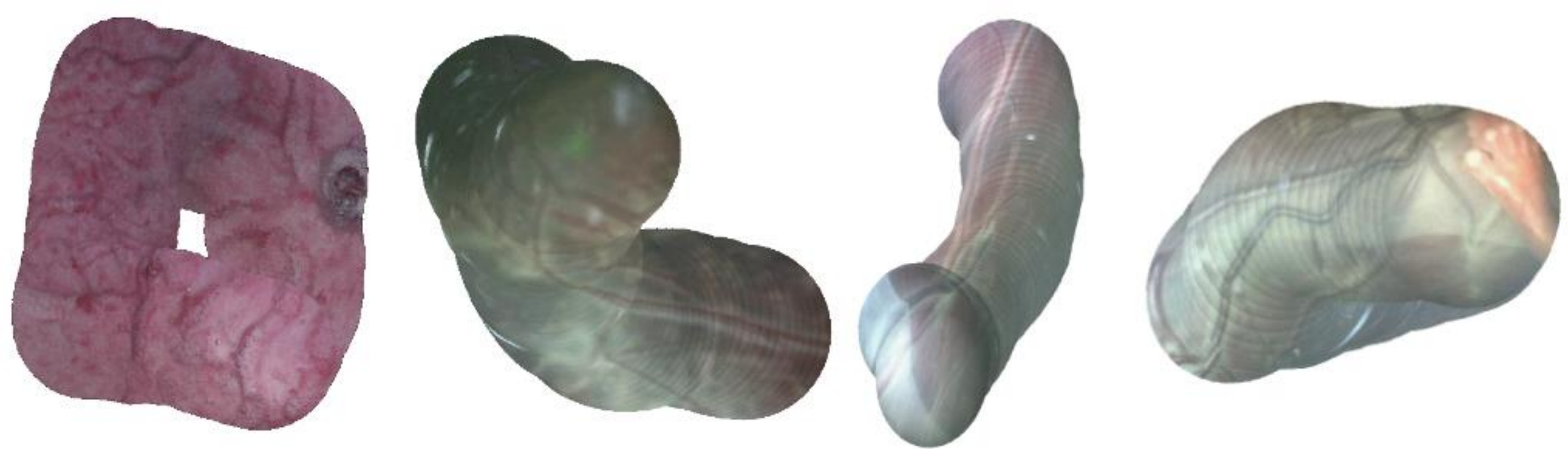
Qualitative stitching and map correction results on a **submerged phantom placenta**:



Conclusion and Discussion

Deep segmentation of placental vessels can increase image stitching accuracy, improving TTTS treatment [1]. Our proposed framework builds upon this concept with:

- **Feature-based homography estimation** to enable real-time image stitching of at least 10 Hz.
- Incorporating a simple **loop closure-based map correction** procedure for the speed-accuracy trade-off.



Future Work: To help overcome limitations of the proposed framework, future work could explore:

- An **optimization-based map correction** procedure to enhance accuracy in more elaborate closed loops.
- Quantitative comparisons to the state-of-the-art U-Net approach [1] for more precise evaluation.

References

[1] S. Bano et al., "Deep placental vessel segmentation for fetoscopic mosaicking," in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, 2020, pp. 763–773.

[2] A. Casella et al., "Toward a navigation framework for fetoscopy," *International Journal of Computer Assisted Radiology and Surgery*, vol. 18, pp. 2349–2356, 2023.

[3] O. Alabi et al., "Robust fetoscopic mosaicking from deep learned flow fields," *International Journal of Computer Assisted Radiology and Surgery*, vol. 17, pp. 1125–1134, 2022.

Demo

Hardware: Intel® Core™ i7-11700 CPU (4.90 GHz), 16 GB RAM, NVIDIA GeForce RTX 2070 SUPER GPU.