DENSE OPTICAL FLOW FOR THE RECONSTRUCTION OF WEAKLY TEXTURED AND STRUCTURED SURFACES: APPLICATION TO ENDOSCOPY

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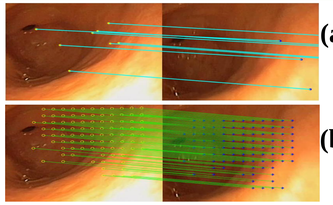
EMMIE Project
ANR-15-CE17-0015

Scientific challenges

- Few textures and structures,
- Illumination changes, few contrast,
- Small field of view, camera close to object surface,
- Artifacts (reflections, saturations, etc.).

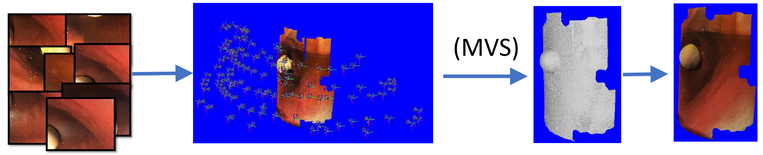


(a) SIFT matches **(b)** Optical flow

Contributions

1. *Adaption of Structure from Motion (SfM)-based methods to the surface reconstruction of hollow organs seen in endoscopic video sequences.*
2. *Proposal of an effective Dense Optical Flow (DOF)-based SfM approach.*
3. *Accuracy evaluation of the proposed method using phantom data and robustness assessment on real medical data (gastroscopy).*

Surface reconstruction pipeline



2D sequence of undistorted images → Structure from Motion (SfM) → (MVS) → Mesh generation → Surface texturing

This work focuses on the determination of homologous points in SfM

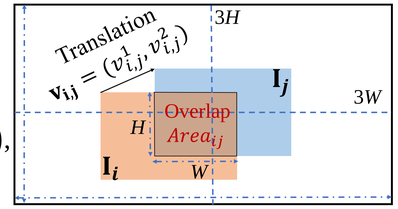
Principle of our SfM pipeline

2D images → **Determination of homologous points groups (HP-groups)** (homologous points between 2D images) → Determination of camera poses and dense 3D point clouds

Proposed DOF-based SfM method

Determination of pairs of overlapped images

- $\mathbf{v}_{i,i+1}\left(v^1_{i,i+1}, v^2_{i,i+1}\right) = \mathbf{OF}_{i,i+1}(\mathbf{c})$, where $\mathbf{c}(W/2,H/2)$ is the image center point and **OF** is the optical flow computed by [**1**].
- $\mathbf{v}_{i,j} = \sum_{t=i_0}^{j_0-1} \boldsymbol{v}_{t,t+1}\left(v^1_{t,t+1}, v^2_{t,t+1}\right)$, where $i_0 = \min(i,j)$, $j_0 = max(i,j)$, $|i-j| > 1$.



- *Image $\mathbf{I}_i$ is called τ-overlapped with image $\mathbf{I}_j$ if the area of $\mathbf{I}_i \cap \mathbf{I}_j$ is greater than τ pixels.*

$$\begin{cases} Area_{ij} = \left(W - \left|v^1_{i,j}\right|\right)\left(H - \left|v^2_{i,j}\right|\right) > \tau, \\ -W < v^1_{i,j} < W, \\ -H < v^2_{i,j} < H \end{cases}$$

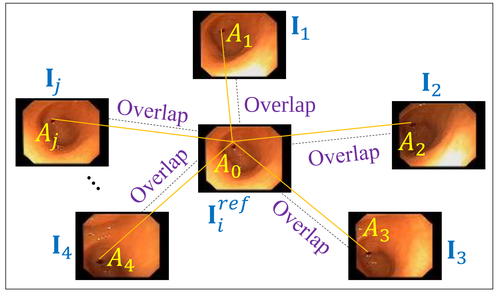
Determination of HP -groups

Observation:

If $(A_0, A_1, \ldots, A_j)$ is a HP-group, then set $(A_0, A_1, \ldots, A_j)$ belongs to an overlapping (common) image region showing a same scene part.

Our idea:

1. Determination for each $\mathbf{I}_i$ of its set of overlapped images.
2. Determination of reference images with Algorithm 1 (paper).
3. Generation of HP-groups.



HP-group definition:

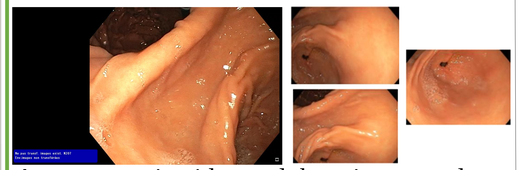
If

- A_0 is a point in a reference image $\mathbf{I}_i^{ref}$ and
- $A_1, \ldots, A_j$ are homologous points of A_0,

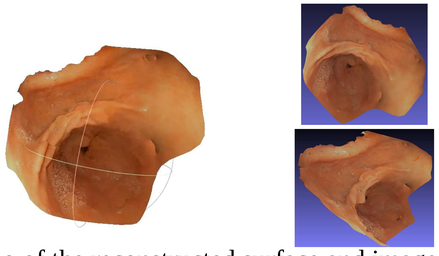
then $(A_0, A_1, \ldots, A_j)$ is defined as a HP-group.

Experimental results

2. Subjective evaluation

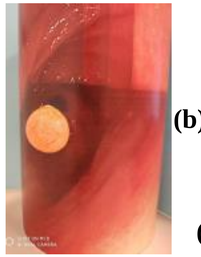


A gastroscopic video and three images selected among the 101 images of the sequence.

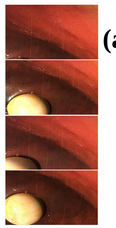


Video of the reconstructed surface and images of the pyloric antrum under two viewpoints.

1. Objective evaluation



(b)



(a)

(c)

(a) Four viewpoints among the 111 images acquired for the phantom. **(b)** Snapshot of the phantom: ${}^{D_{GT}}/_{d_{GT}} = 3.972$. **(c)** Surface reconstructed by the proposed method: ${}^{D}/_{d} = 3.945$.

D, D_{GT}: computed cylinder diameter and ground truth. d, d_{GT}: computed sphere diameter and ground truth.	3D shape criterion (%) $p = \left(1 - \frac{\left\lvert {}^{D_{GT}}/_{d_{GT}} - {}^{D}/_{d} \right\rvert}{{}^{D_{GT}}/_{d_{GT}}}\right)$	Outlier rate (in %)	Mean outlier error (in *mm*)	Computation time (seconds)
Proposed method	99.33%	6.18%	5.65 mm (3.54%D_{GT})	4749
COLMAP ([**2**]) +MVS	99.48%	7.48%	6.92 mm (4.34%D_{GT})	2646

References

[**1**] D.-H. Trinh and C. Daul, "On illumination-invariant variational optical flow for weakly textured scenes," *Computer Vision and Image Understanding*, vol. 179, pp. 1–18, 2019.

[**2**] J. L. Schonberger and J.-M. Frahm, "Structure-from-motion revisited," in *IEEE Conf. on Computer Vision and Pattern Recognition*, 2016, pp. 4104–4113.