The Centre for Medical Image Computing

BIOPSY SITE RE-LOCALISATION WITH EPIPOLAR LINES DERIVED FROM TWO PREVIOUS ENDOSCOPIC IMAGES

Allain B.[1], Hu M.[1], Lovat L. B.[2], Cook R. J.[3], Ourselin S.[1], Hawkes D. J.[1]

b.allain@ucl.ac.uk

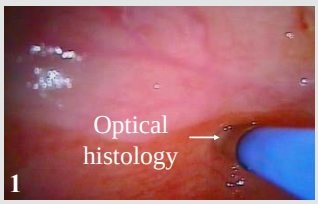
[1]The Centre for Medical Image Computing (CMIC), University College London
[2]Department of Gastroenterology, University College London Hospitals, Foundation Trust and National Medical Laser Centre, Division of Surgical Sciences
[3]Dental Institute, Department of Biomaterials, King's College London

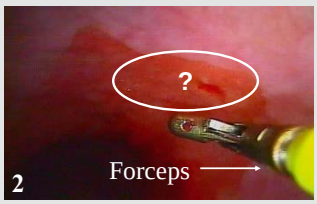
Abstract

Tracking biopsy sites in endoscopic images can be useful to provide a visual aid for the guidance of surgical tools, for example when endoscopic guided biopsy is required. We present a new method which re-localises a site in an image of an endoscopic sequence as the intersection of 2 epipolar lines derived from 2 previous images. The re-localisation accuracy was estimated at less than 1mm for gastroscopic data.

1. Problem

- **Context:** For some endoscopies, an **'optical'** ***in vivo*** **histology** helps detect pathologies that are **invisible macroscopically** before excision with **forceps**.
- **Problem:** The optical measurement and the excised tissue **may not match**, which can make the **biopsy irrelevant** if negative **[1][2]**.
- **Purpose:** A biopsy site needs to be **re-localised** in subsequent video images.

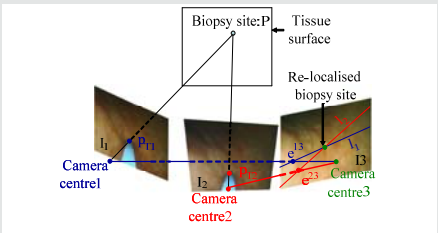




2. Method

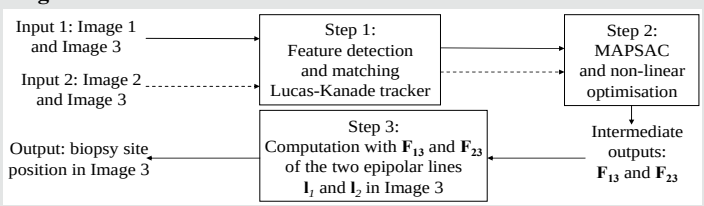
- **Need:**
  - The **spatial transformation** from one endoscopic image where the biopsy site location is known to the target image has to be computed.

  ⇒ Computation of the transformation between endoscopic images with **epipolar geometry [3]**.



- **Idea:**
  - The fundamental matrix $\mathbf{F_{13}}$ contains information about spatial transformations between two images I1 and I3.
  - A biopsy site $\mathbf{p_{T1}}$ known in image I1 projects onto image I3 as a line $\mathbf{l}_1 = \mathbf{F_{13}}\mathbf{p_{T1}} = [\, l_{1x}, l_{1y}, l_{1m} \,]^T$ so $x.l_{1x} + y.l_{1y} + l_{1m} = 0$.
  - A second image gives a second line $\mathbf{l}_2 = \mathbf{F_{23}}\mathbf{p_{T2}}$: the biopsy site is at the intersection of $\mathbf{l}_1$ and $\mathbf{l}_2$ **[4]**.

- **Algorithm:**



3. Validation and Results

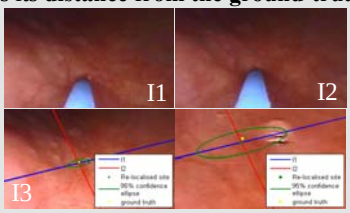
- **Purpose:** Estimate the **precision** and the **accuracy** of the re-localisation.
- **Data:** 9 groups of 3 images (I1-I2-I3) from 3 different patients were acquired during a gastroscopy for the diagnosis of Barrett's Oesophagus. The Field Of View (FOV) of I3 was approximately 10mm x 10mm for 3 groups and 10mm x 15mm for 6 groups.
- **Method:**
  - Each fundamental matrix ($\mathbf{F_{13}}$ and $\mathbf{F_{23}}$) is computed N times to estimate an **average matrix** and **the covariance** of the 9-vector, $\mathbf{f_{13}}$ and $\mathbf{f_{23}}$, of the matrix **[5]**:

$$\bar{\mathbf{F}}_{i3} = \frac{1}{N}\sum_{j=1}^{N}\mathbf{F}_{i3\,j} \text{ and } \Lambda_{\mathbf{f}_{i3}} = \frac{1}{N-1}\sum_{j=1}^{N}\left[\left(\mathbf{f}_{i3\,j} - \bar{\mathbf{f}}_{i3}\right)\left(\mathbf{f}_{i3\,j} - \bar{\mathbf{f}}_{i3}\right)^{\mathrm{T}}\right] \quad , \quad i \in \{1, 2\}.$$

  - The **mean of the line** and **its covariance** are computed **[5]**:

$$\bar{\mathbf{l}}_i = \bar{\mathbf{F}}_{i3}\mathbf{p}_{Ti} \;,\; i \in \{1, 2\} \text{ and } \Lambda_{\mathbf{l}_i} = \frac{\partial \mathbf{l}_i}{\partial \mathbf{f}_{i3}}\left(\bar{\mathbf{f}}_{i3}\right)\Lambda_{\mathbf{f}_{i3}}\frac{\partial \mathbf{l}_i}{\partial \mathbf{f}_{i3}}\left(\bar{\mathbf{f}}_{i3}\right)^{T}.$$

  - The re-localised biopsy site is the **intersection** of $\bar{\mathbf{l}}_1$ and $\bar{\mathbf{l}}_2$.
  - **Its precision** is found by **propagation** of $\Lambda_{\mathbf{l}_1}$ and $\Lambda_{\mathbf{l}_2}$.
  - **Its accuracy** is its **distance from the ground-truth**.



	Patient 1				Patient 2			Patient 3	
Groups I1-I2-I3	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
FOV of I3 (mm)	8x14	8x14	16x20	16x20	14x12	8x10	10x16	10x15	15x15
Precision (mm)	0.2	0.3	0.8	0.9	0.7	0.2	0.9	0.6	0.9
Accuracy (mm)	0.2	0.2	0.2	0.7	0.7	0.2	1.0	0.5	0.9

4. Discussion

- **Advantages:**
  - **Direct use of epipolar geometry properties** without computing the rotations and the translations of the endoscope camera.
  - Re-localisations at **less than 1mm**.
  - Point precision useful for the **detection of bad re-localisations**.
  - Possible use of this method for other **endoscopic applications.**
- **Drawbacks:**
  - Need of a **good contrast** in the images for feature matching.
  - Relatively **large camera motions required**: if the two lines form a narrow angle, the biopsy site may be badly re-localised.
  - **Accurate correspondence** of $\mathbf{p_{T1}}$ and $\mathbf{p_{T2}}$ required.

5. References

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b.allain@ucl.ac.uk, CMIC, UCL