# Texture-Based Region Tracking Using Gaussian Markov Random Fields for Cilia Motion Analysis

Yasseen Almakady

University of Southampton, United Kingdom

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# Introduction

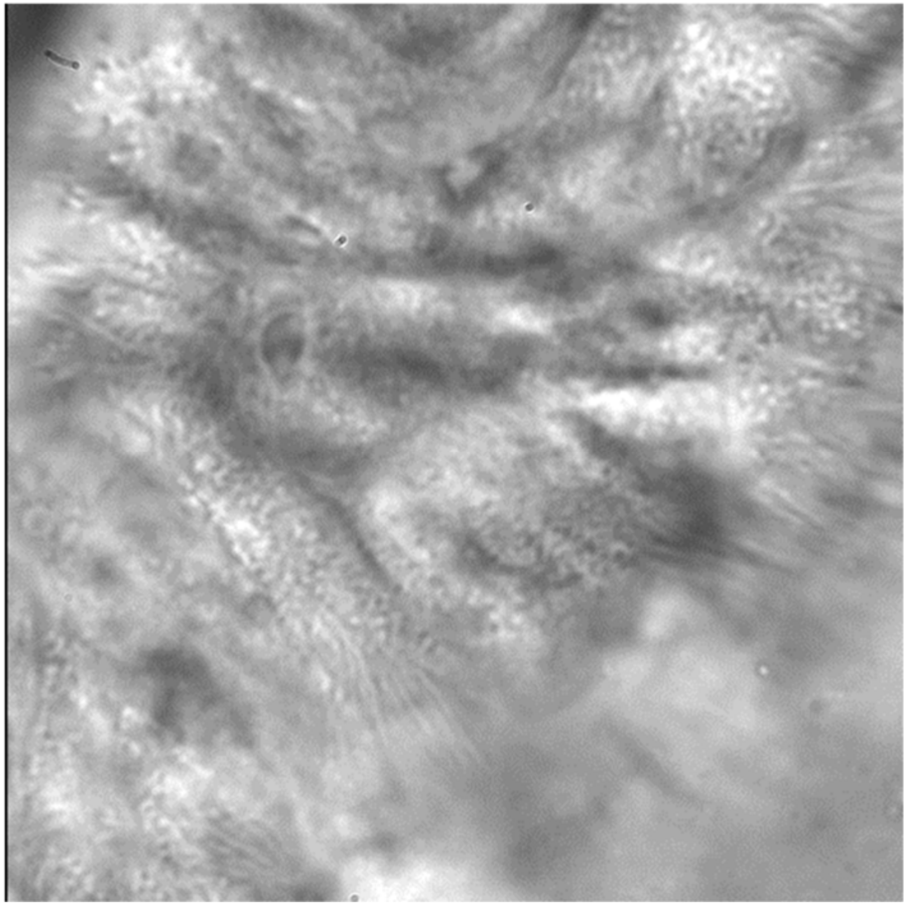
- Motile Cilia
  - Protect the respiratory system.
  - Protection function is performed by ciliary beating.
  - Defect on this function leads to the impairment of Mucociliary clearance.
  - Primary ciliary dyskinesia (PCD) is associated with ciliary beating abnormality .

- Ciliary beating motion (CBM)
  - Tracking (CBM) to understand its behaviour.
  - Beneficial for diagnosis.

# Introduction

- Challenges
  - Low contrast.
  - Moving textured regions.
  - Textures regions are moving with textured background.
  - Camera calibration.

- Proposed solution
  - Ciliary beating appears as a moving texture.
  - Region tracking based on texture feature.
  - Extract CBM trajectory.



# Method

- Method overview

Video → Preprocessing → Feature extraction → Region tracking → Motion Trajectory extraction

**Preprocessing**: **Optical flow** is used to extract regions of interest i.e. beating cilia area

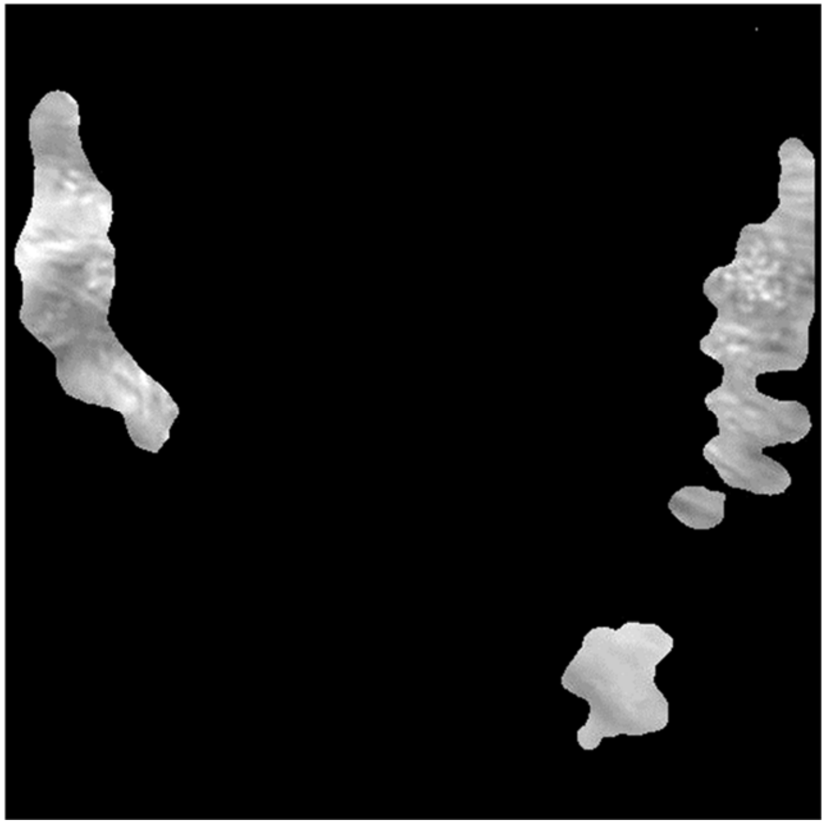
**Feature extraction**: **Texture feature** is extracted using GMRF

**Region tracking**: **Region tracking** is performed using block-matching search technique based on GMRF features

**Motion Trajectory extraction**: **trajectory vector** of the tracked region is extracted depicting the pattern of *cilia motion* over all frames

# Preprocessing

- Optical flow
  - Region of interest i.e. beating cilia regions
    - The optical flow is estimated using Horn-Schunck method.
    - The *magnitude components* are accumulated.
    - The accumulated magnitude at specific threshold is considered to extract beating cilia regions
  - Advantage: Less computation time is required



# Feature extraction

- Gaussian Markov Random Fields model.

$$p(g_s|y_{s+r}, r \in N) = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left\{ -\frac{1}{2\sigma^2}\left(g_s-\lambda-\sum_{r\in N}\alpha_r(y_{s+r}-\lambda)\right)^2 \right\}$$

- $g_s$ : Value of central pixel.
- $y_r$ : Intensity values of neighbours.
- $\lambda$ : Mean of the processed region.
- $\alpha_s$ : Interaction parameters (coefficient).
- $\sigma^2$ : Variance.
  - **Parameters to be estimated.**
    1. $\alpha_s = [\alpha_1, \alpha_2, \ldots \alpha_r]$
    2. $\sigma_s^2$

| | | |
|---|---|---|
| $y_1$ | $y_2$ | $y_3$ |
| $y_8$ | $g_s$ | $y_4$ |
| $y_7$ | $y_6$ | $y_5$ |

**Neighbourhood scheme**

# Feature extraction

- Local estimation of parameters $\alpha_s$ , $\sigma_s^2$
- Maximum likelihood estimation (MLE)

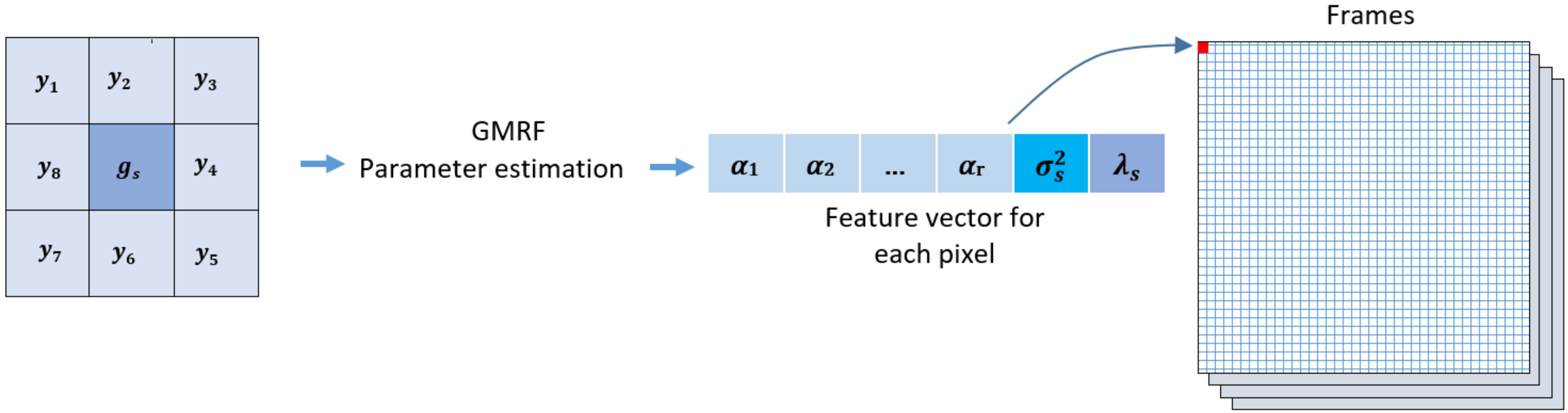
  - Solution :

$$\boldsymbol{\alpha}_s = \left( \sum_{s \in \Omega_s} \boldsymbol{y}_s \boldsymbol{y}_s^T + cI \right)^{-1} \left( \sum_{s \in \Omega_s} \boldsymbol{y}_s g_s \right)$$

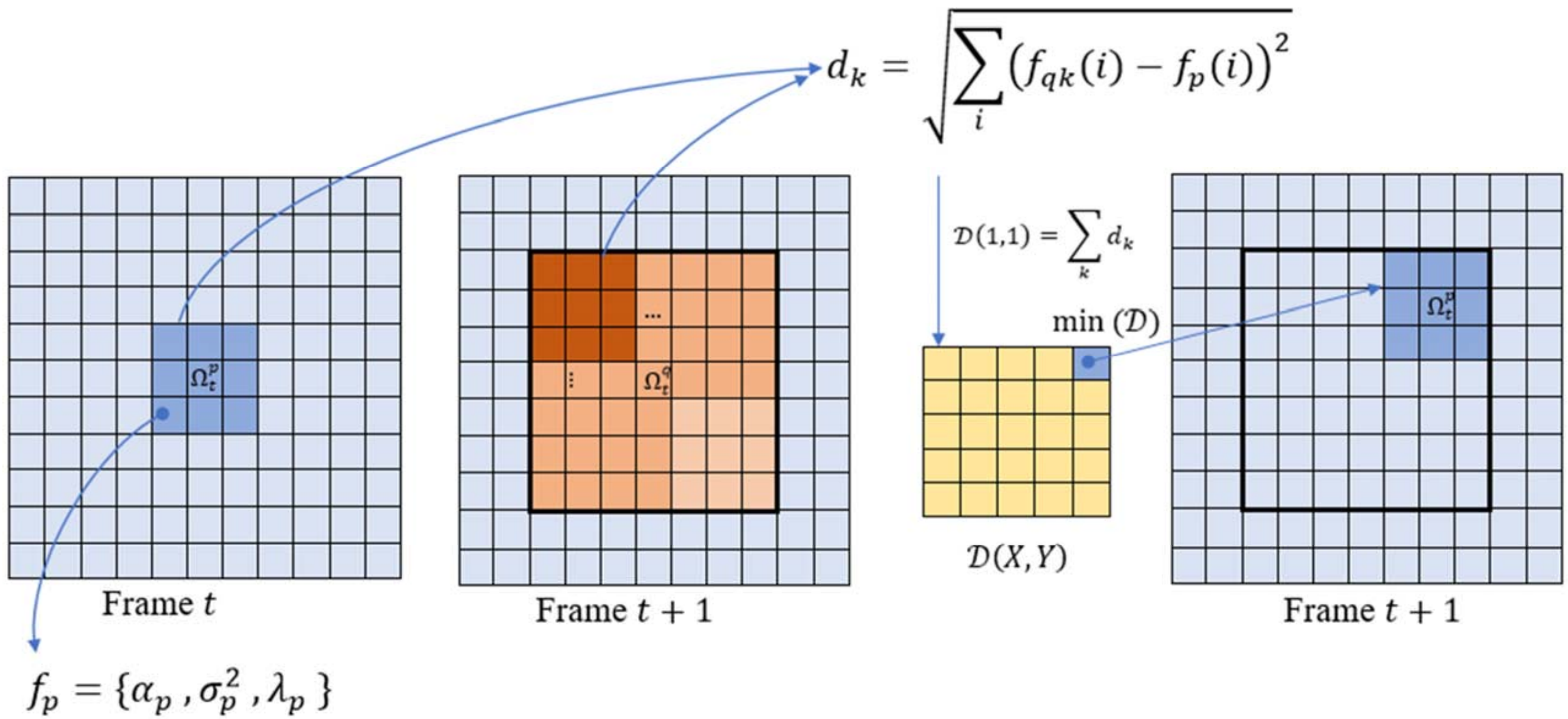
$$\sigma_s^2 = \frac{1}{|\Omega_s|} \sum_{s \in \Omega_s} (g_s - \boldsymbol{\alpha}_s \boldsymbol{y}_s)^2$$

*C* : Regularisation parameter.
*I* : Identity matrix

# Feature extraction

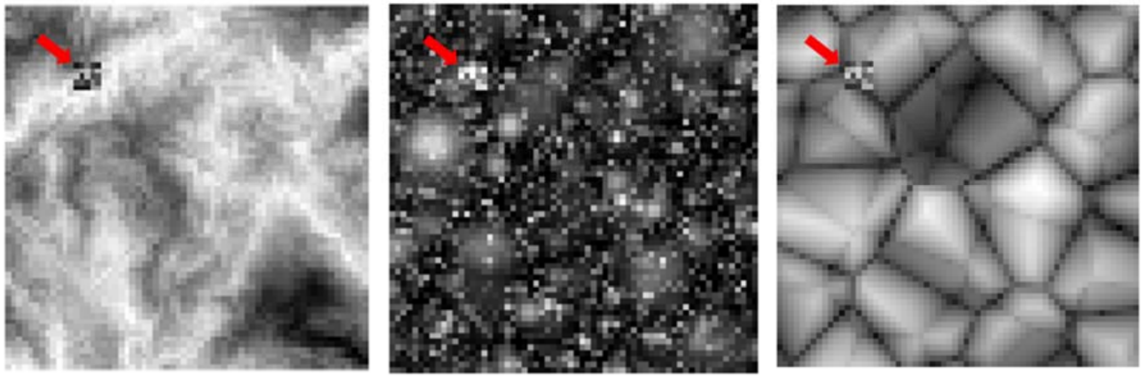


# Region tracking



# Evaluation

- Synthetic samples
  - Size 64x64 , 64 frames



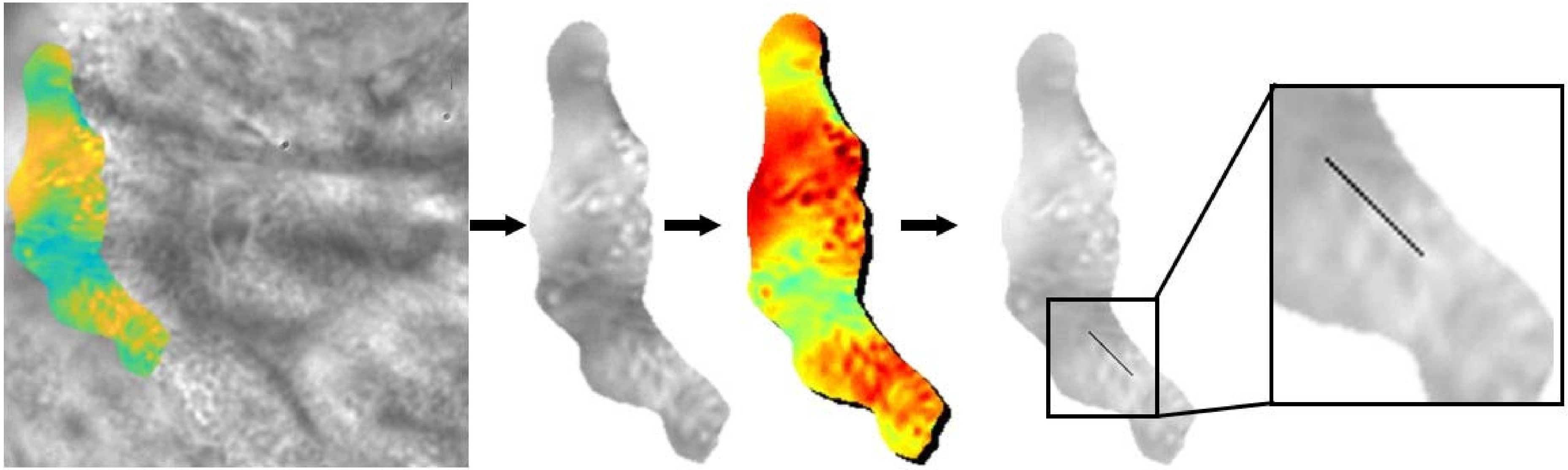
Samples

Ground truth

| Neighborhood | w = 3 | w = 5 | w = 7 |
|---|---|---|---|
| Distance | 2.53± 1.54 | 8.20±3.37 | 19.71±7.70 |

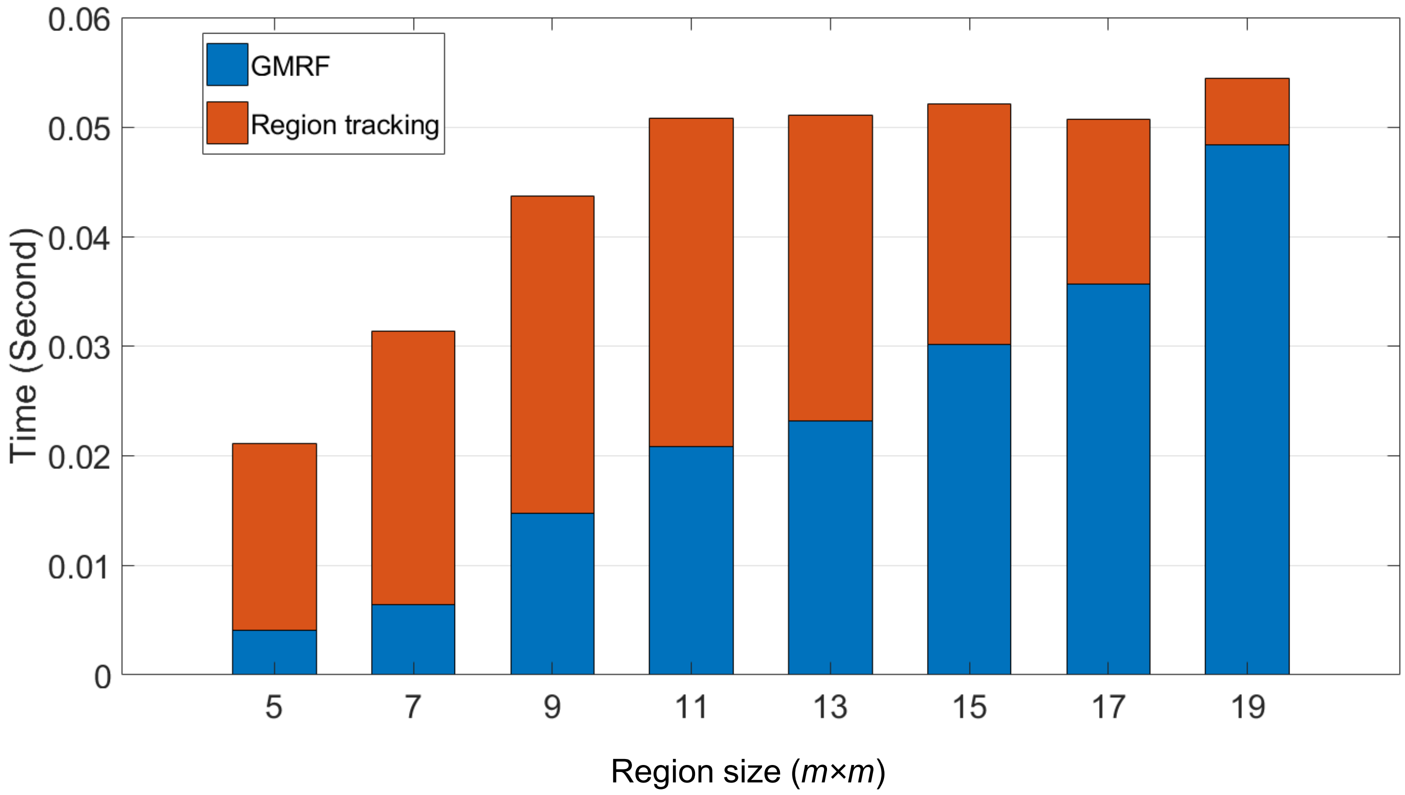
# Evaluation

- Medical sample of cilia video *Size 512x512 , 512 frames*



| Neighborhood | w = 3 | w = 5 | w = 7 |
|---|---|---|---|
| Distance | 21.48±8.45 | 2.80± 5.59 | 4.72 ± 4.0 |

# Performance



# Conclusions

- A new method for region tracking based on texture feature is proposed for cilia motion tracking.
- Experiments outcome demonstrates the capability of texture feature to track a textured region under different challenges.

# Thank You!