Design Space Exploration for Adaptive Privacy Protection in Airborne Images

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Outline

- Introduction and Motivation
- Literature Review
- Proposed Work
- Experimental Results
- Conclusion and Future Work

Introduction

[James, 2014]

[Leigh, 2014]

[Simon, 2014]

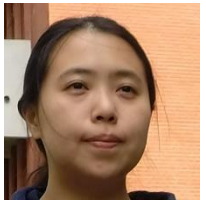
[Kurt, 2015]

Motivation

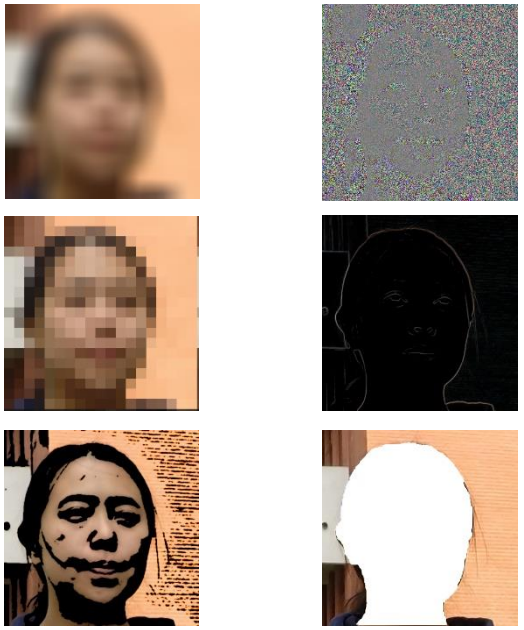
- How we can protect privacy in airborne cameras (intended for recreational applications), while maintaining high fidelity of the visual data ?
- Sub-problems
  - Exploring privacy design space
  - Configuring a privacy adaptive filter

Background

- Privacy Filters in CCTV
  - Adaptive filters
    - Pixelation [Zhao, 1998]
    - Blurring [Wickramasuriya, 2004]
    - Cartooning [Erdelyi, 2014]
    - Scrambling [Zeidler, 1994]
    - Warping [Korshunov, 2013]
  - Non-adaptive filters
    - Box [Wickramasuriya, 2004]
    - Avatar [López, 2015]
    - Edge [Zhao, 1998]
    - Transparency [Chinomi, 2008]
    - Silhouette [Tansuriyavong, 2001]



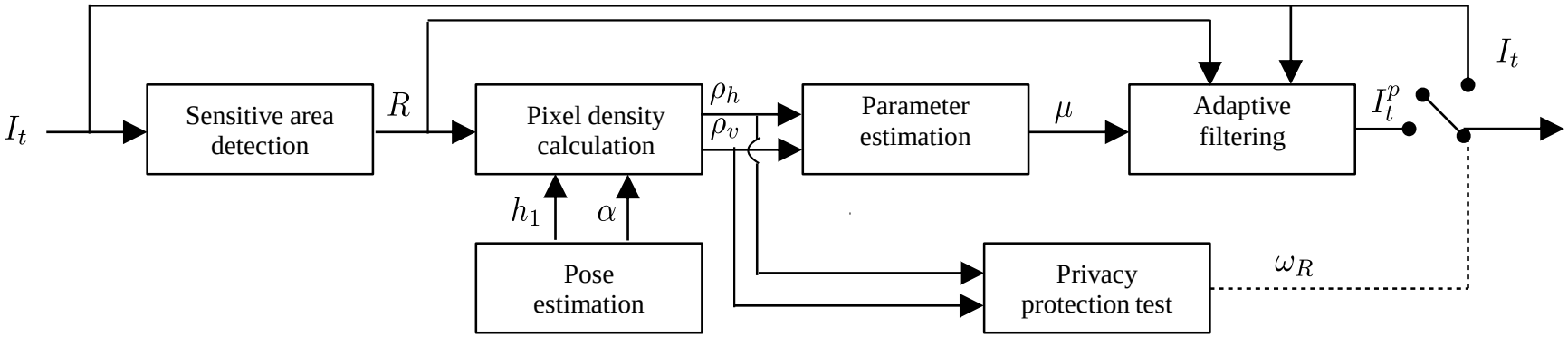
[Hsu, 2015]



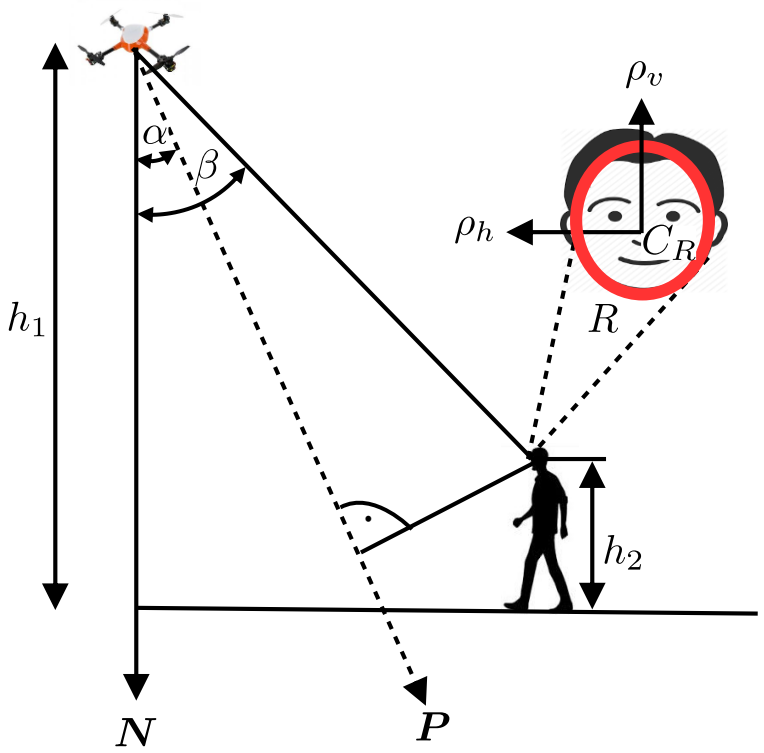
Background

- Privacy in Airborne Cameras
  - Geo-fencing
    - NoFlyZone [www.noflyzone.org]
    - Broadcast privacy beacons [Vaidya, 2015]
  - Processing ROI
    - Encrypted videos [Kim, 2014]
    - Unmanned Aerial System- Visual Privacy Guard (UAS-VPG) [Babiceanu, 2015]

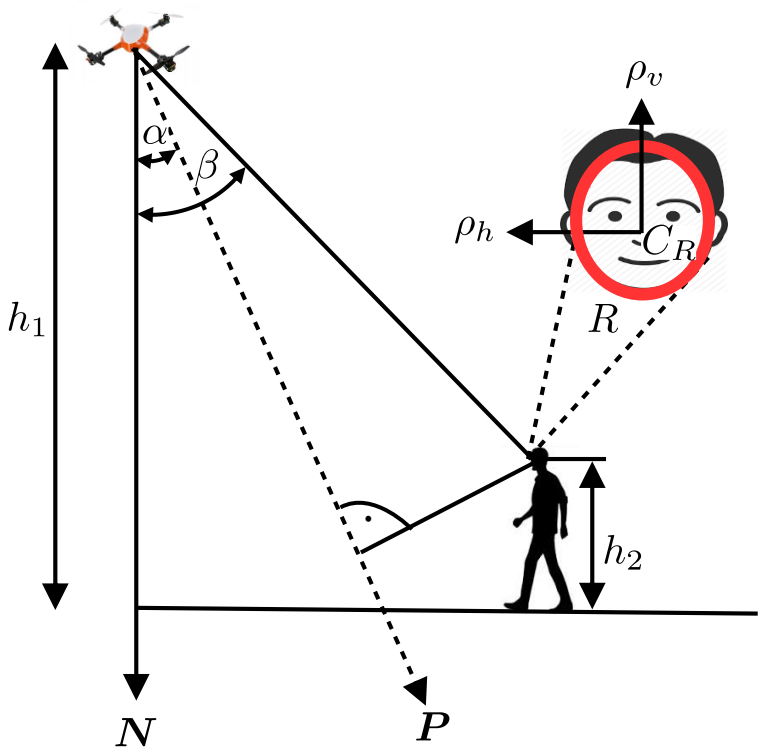
Proposed approach



Proposed approach



Proposed approach



focal length

$$\rho_h = \frac{f cos(\beta)}{p_h(h_1 - h_2)}$$

horizontal pixel size

$$\rho_v \approx \frac{f cos(\beta) sin(\beta)}{p_v(h_1 - h_2)}$$

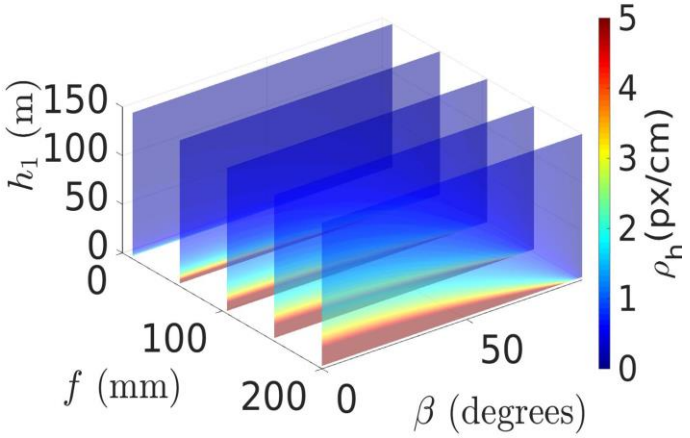
vertical pixel size

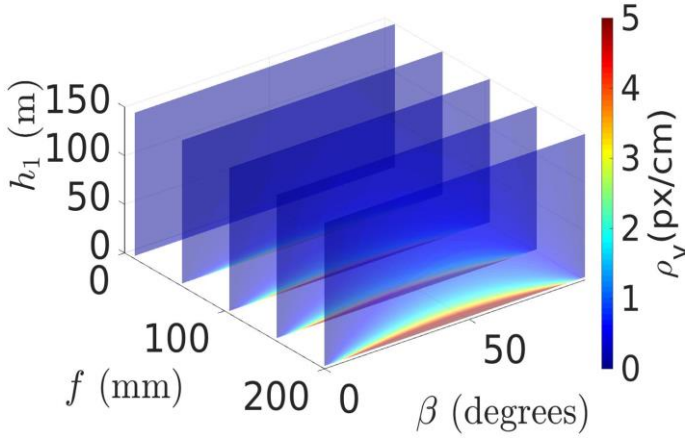
Privacy design space

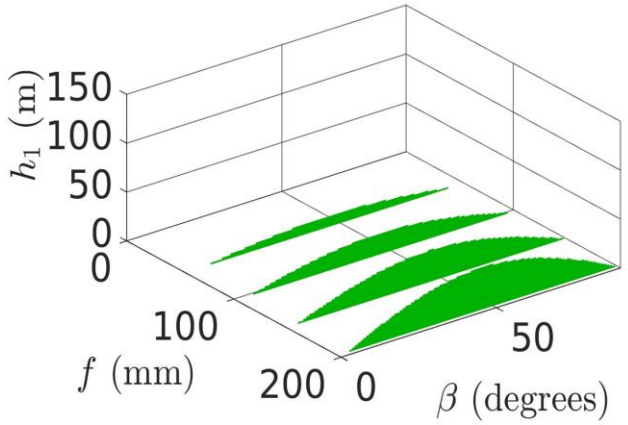
experimentally determined thresholds

$$\omega_R = \begin{cases} 1 & if \quad \rho_h > \rho_h^0 \quad \& \quad \rho_v > \rho_v^0 \\ 0 & otherwise \end{cases}$$

Analytical results (Canon EOS 5D MARK II)

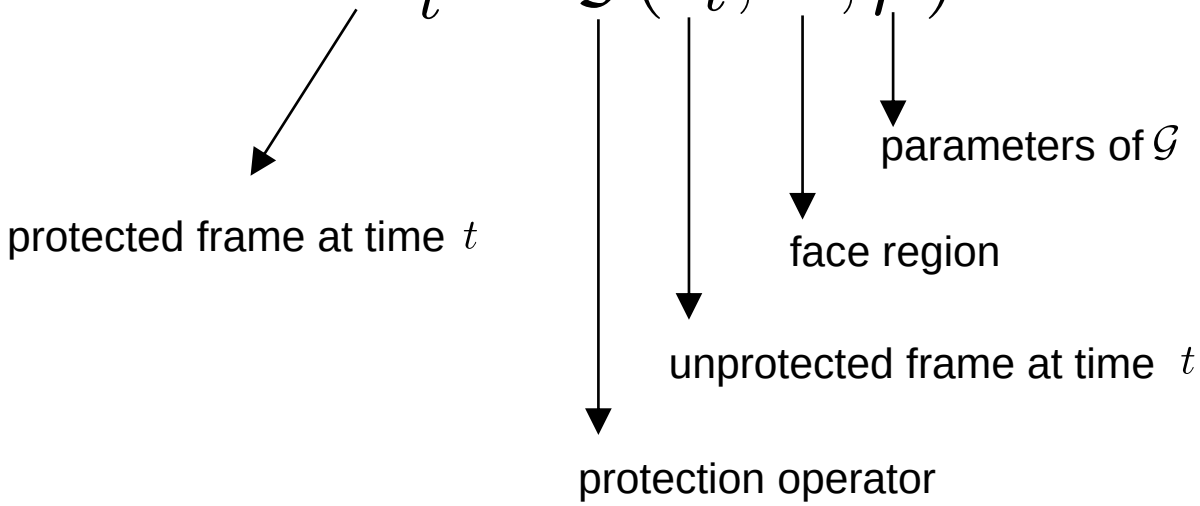






Adaptive privacy filter

$$I_t^p = \mathcal{G}(I_t, R, \mu)$$



Adaptive Gaussian blur

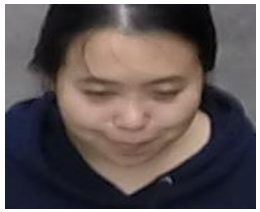
$$g(h,v) = \frac{1}{2\pi\sigma_h\sigma_v} e^{-(\frac{h^2}{2\sigma_h^2}+\frac{v^2}{2\sigma_v^2})}$$

$$\sigma_i = \frac{3\rho_i}{\pi\rho_i^0} \qquad \text{where} \quad i \in \{h,v\}$$

$$\mu_i = 2\lceil 3\sigma_i \rceil + 1$$

Standard deviation of anisotropic Gaussian function $g(h,v)$

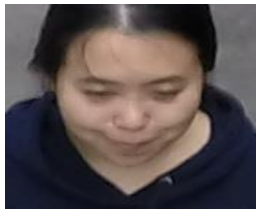
Adaptive Gaussian blur example



$(5.03, 3.88)$

Original

Adaptive Gaussian blur example



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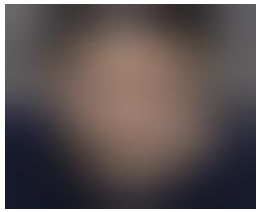


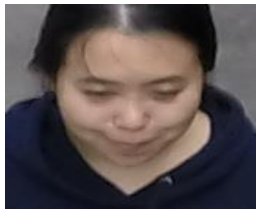
$(121, 105)$

Original

Fixed*

*Gaussian Blur for LDA face recognizer
Fixed: w.r.t. highest pixel density image in the data

Adaptive Gaussian blur example



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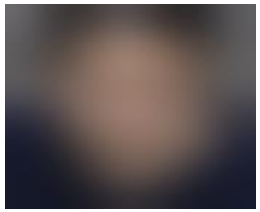

$(121, 105)$

$(99, 77)$

Original Fixed* Over*

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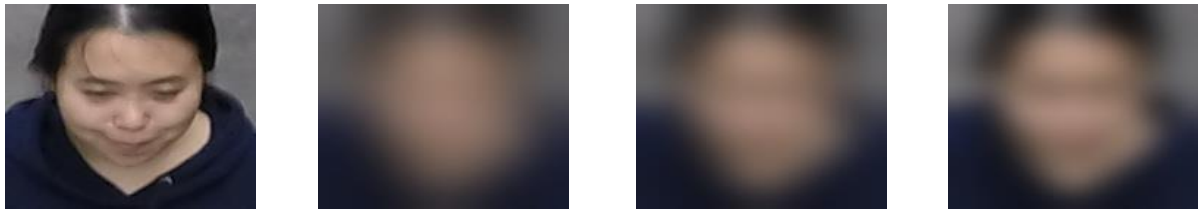
Adaptive Gaussian blur example



$(5.03, 3.88)$ $(121, 105)$ $(99, 77)$ $(75, 57)$

Original Fixed* Over* Optimal*

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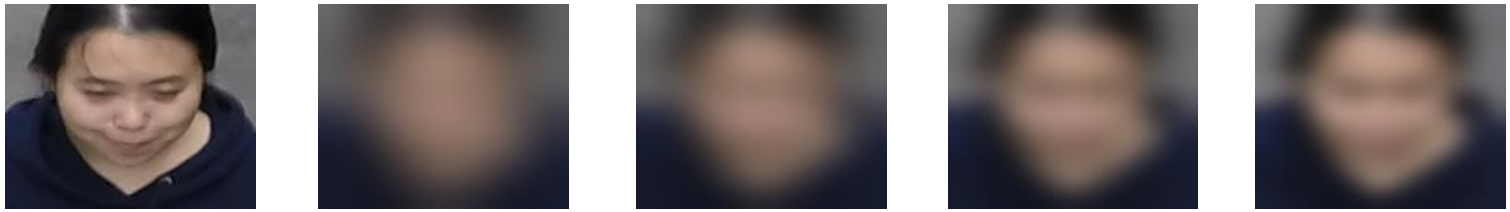
Fixed: w.r.t. highest pixel density image in the data

Adaptive Gaussian blur example



$(5.03, 3.88)$ $(121, 105)$ $(99, 77)$ $(75, 57)$ $(59, 47)$

Original Fixed* Over* Optimal* Under*

*Gaussian Blur for LDA face recognizer
Fixed: w.r.t. highest pixel density image in the data

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Experimental set-up

- Dataset “Face Recognition on Drones: Issues and Limitations [Hsu, 2015]”
  - Population Size: 11 persons
  - Test Data: 693 (63 x 11) images collected from 63 different positions.
  - Training Data: 121 images i.e. 11 images of each person.

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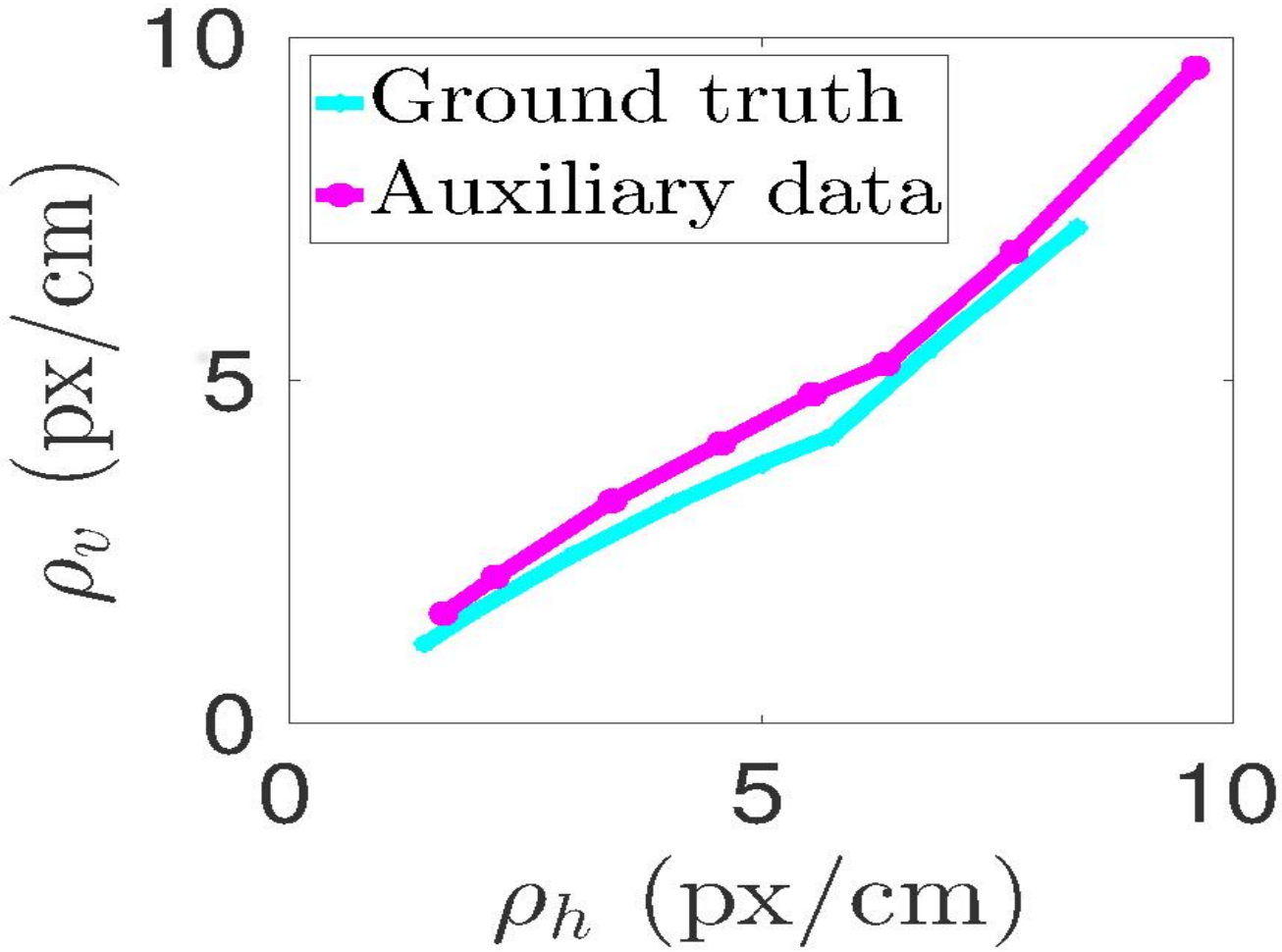
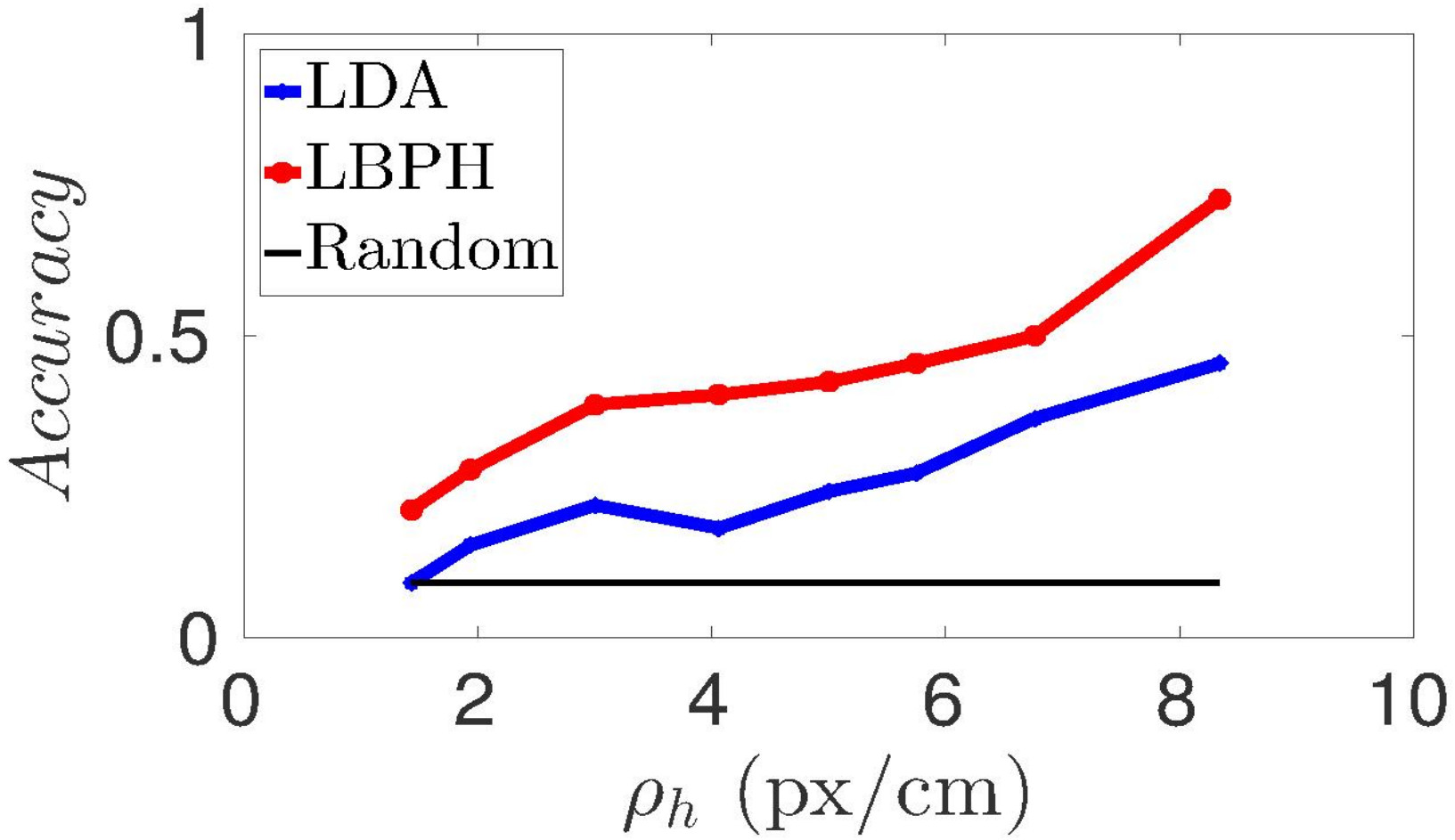
- Fidelity measurement:
  - Peak Signal to Noise Ratio (PSNR)
  - Structural Similarity Index Metric (SSIM) [Wang 2004]

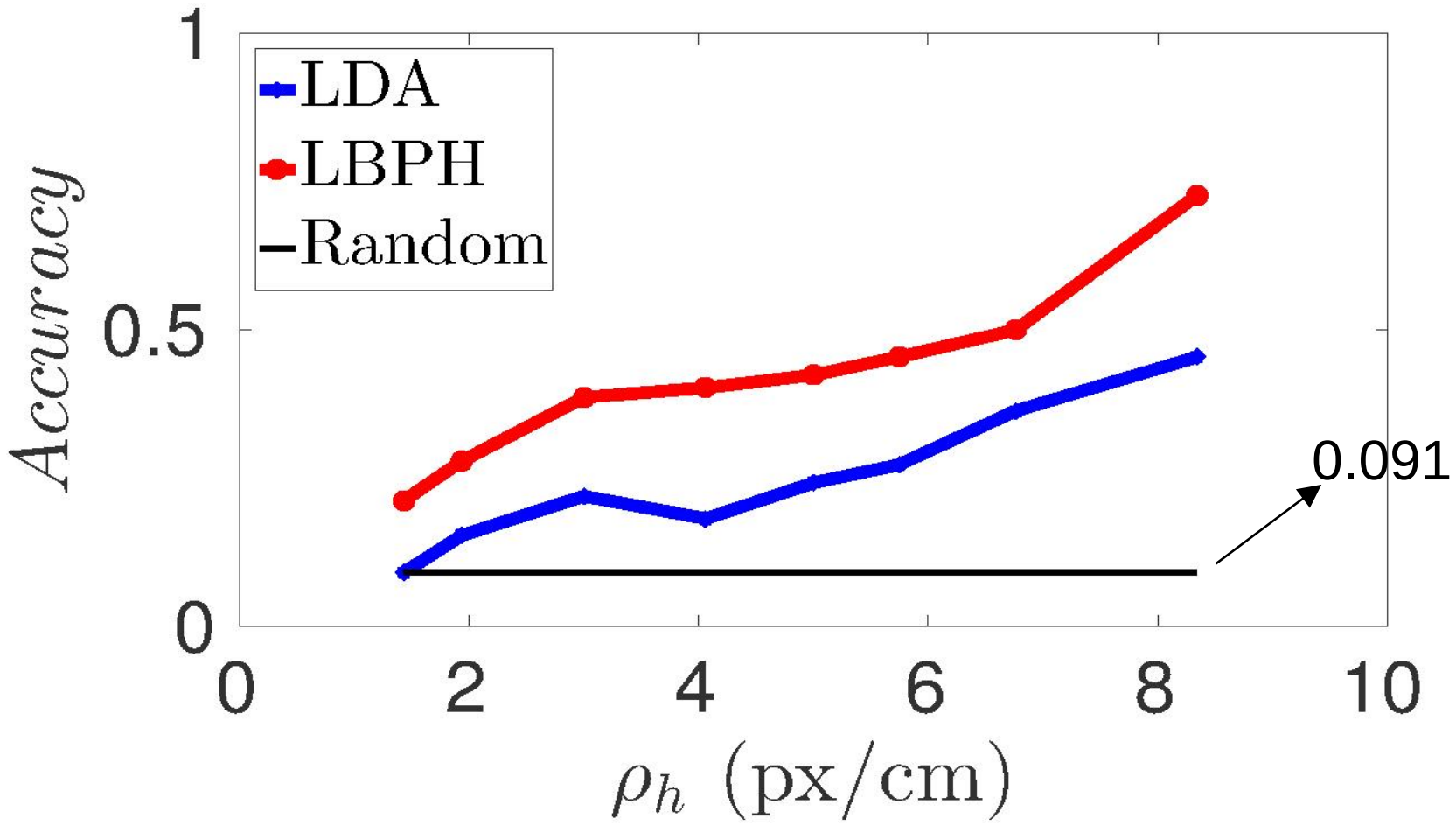
Pixel density of selected data



Recognition accuracy

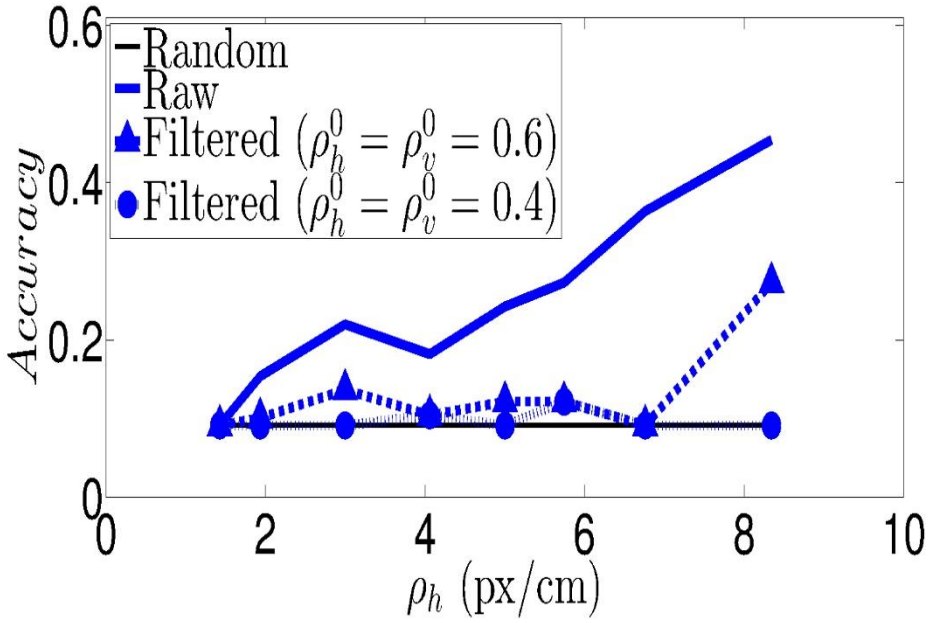


Recognition accuracy

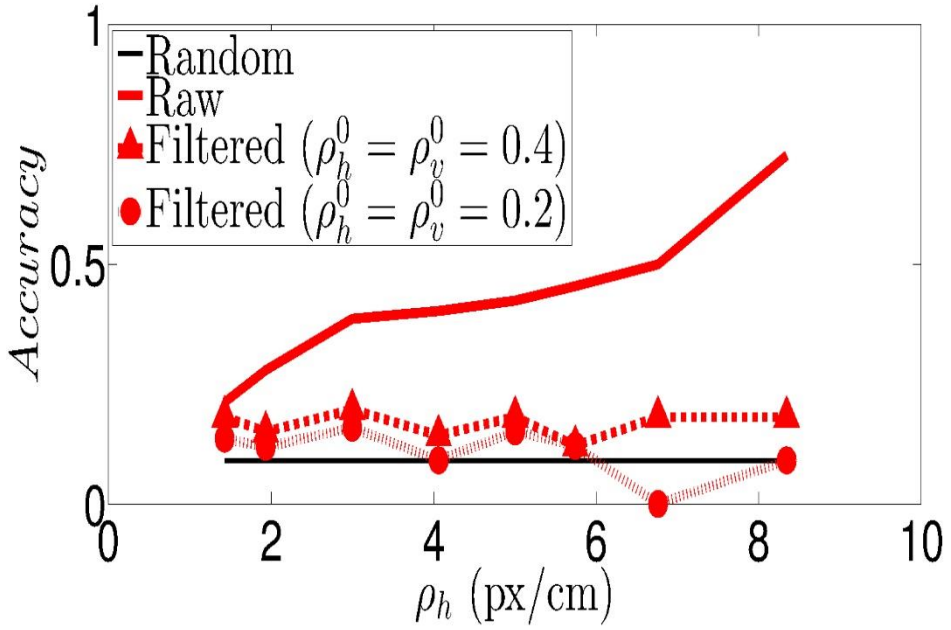


Adaptive Gaussian filter

LDA face recognizer

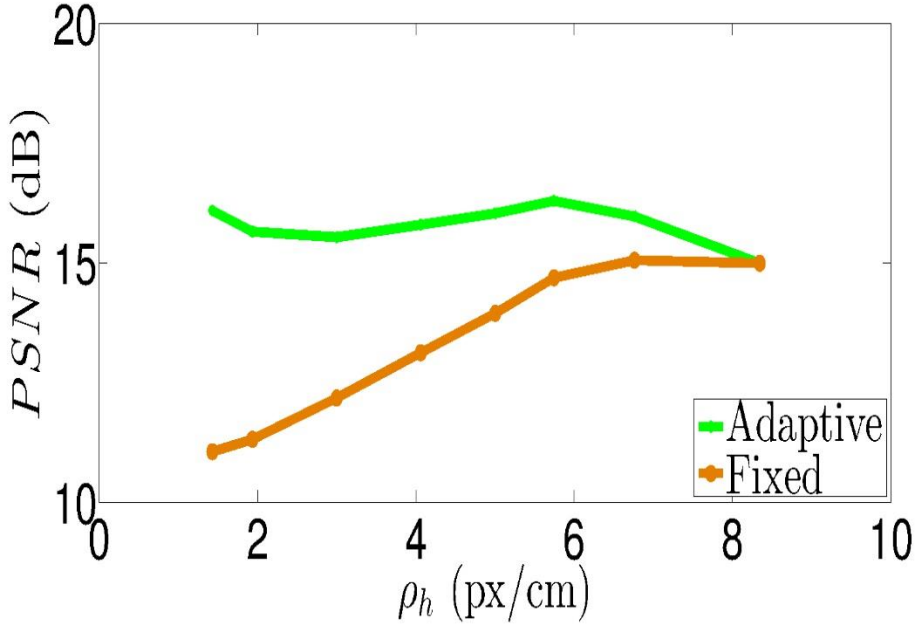


LBPH face recognizer

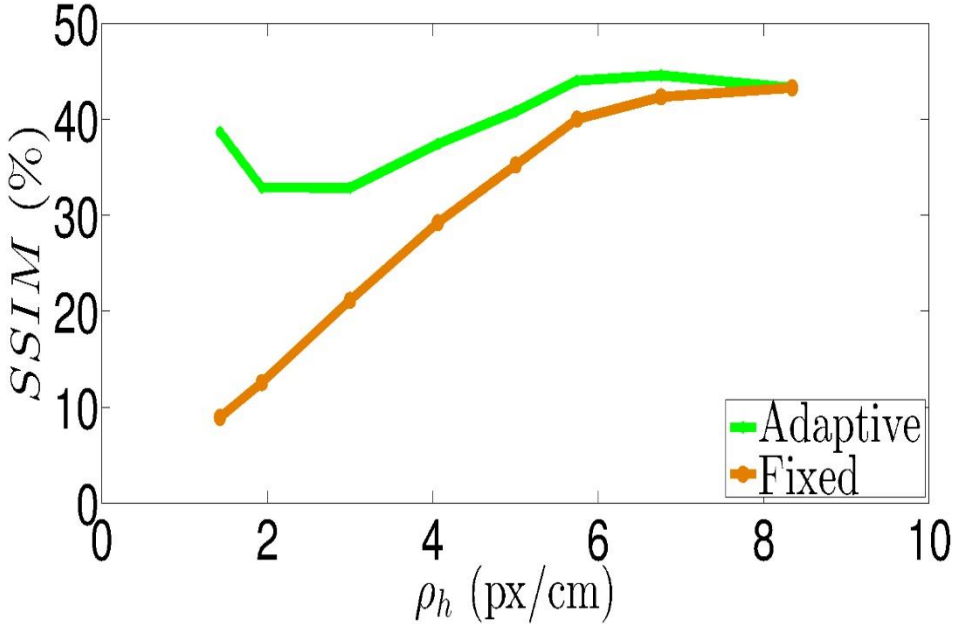


Fidelity measurement

Peak Signal to Noise Ratio (PSNR)



Structural Similarity Index Metric (SSIM)



Conclusions

- Separated inherently protected and unprotected space.
- Proposed an adaptive filtering approach, which provides high fidelity while still providing same amount of privacy protection as fixed filter.

- Future Work
  - Super resolution attack.
  - Benchmarking with recent face recognition algorithms.
  - Developing/testing with data set having large population size.

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