# Deep Compressive Sensing for Visual Privacy Protection in FlatCam Imaging

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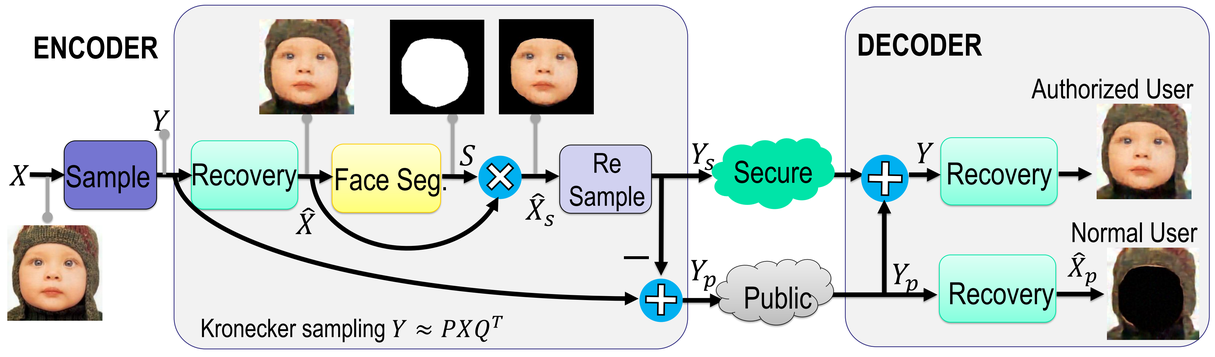
Source code — OPEN 2021 — 大阪大学 OSAKA UNIVERSITY

## 1. Introduction

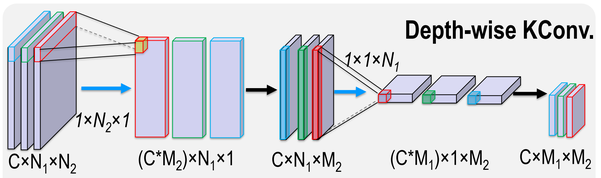
- Detection then protection is vulnerable to software attack.
- FlatCam[1,2] captures visually protected but not privacy protected image & low recovery quality.
- We improved reconstruction with a deep residual learning network.
- We protect sensitive regions from FlatCam measurement via a deep visual privacy network.




***Proposed Deep Visual Privacy Protection Framework***

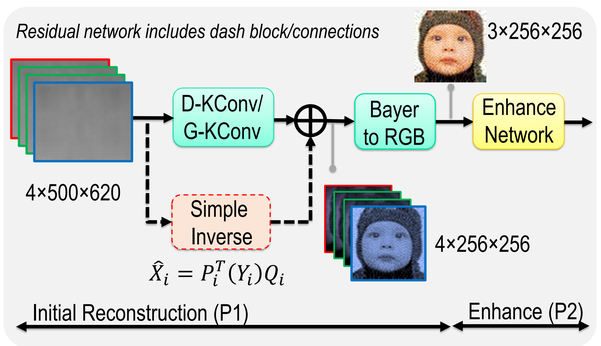
## 2. Deep FlatCam Reconstruction

- Initial reconstruction with Kronecker Conv. (KConv)



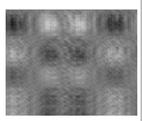
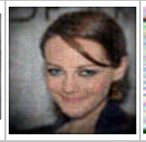
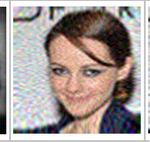
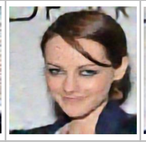
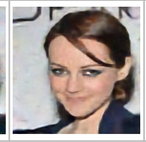
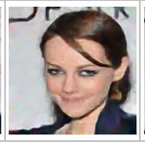
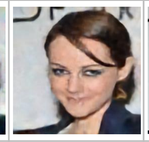
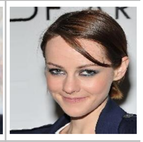
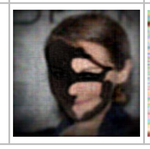
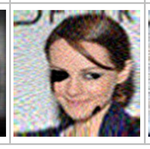
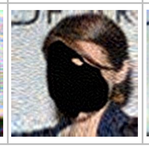
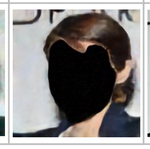

- Residual Reconstruction framework – two phases[2]

*Utilize the calibrated sampling matrices P, Q*

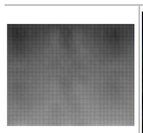
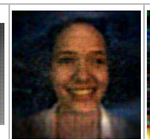
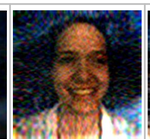
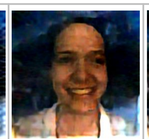
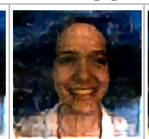
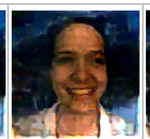
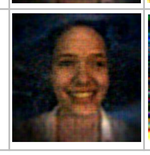
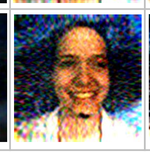
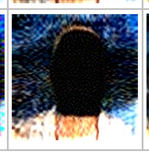
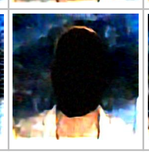
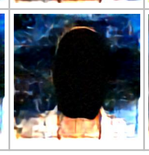
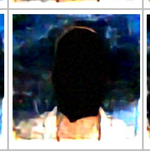
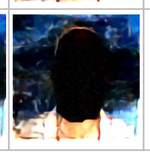



## 5. Visual Quality of Reconstruction and Visual Privacy Protection

**Simulated FlatCam Measurement**

| Meas. $Y$ | Non-DL [1] | D-KConv-P1 | G-KConv-P1 | D-KConv-P2 | G-KConv-P2 | D-KConv-P2* | G-KConv-P2* | Groundtruth |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |
| |  |  |  |  |  |  |  |  |

**Real FlatCam Measurement from [2]**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  | NA |
| |  |  |  |  |  |  |  | NA |

*First and third row: the reconstructed images - $\hat{X}$; second and forth row: the privacy protected images - $\hat{X}_p$*
*Residual networks are marked with (*)*

**Related Work**

[1] M. S. Asif et al. Thin, lensless cameras using coded aperture and computation. IEEE Trans. Computational Imaging (TCI), 2017
[2] J. Tan et al. Face detection and verification using lensless cameras. *IEEE Transaction on Computational Imaging (TCI)*, June 2019
[3] T. N. Canh et al. Multi-scale deep compressive sensing network. *IEEE Inter. Conf. Visual Comm. Image Processing (VCIP)*, Dec. 2018.

## 3. Visual Privacy Protection

- Privacy protection in spatial domain ($\hat{X}_p$)

$$\hat{X} = \hat{X}_p + \hat{X}_s \quad s.t. \quad \hat{X}_s = S \odot \hat{X}$$

- Privacy protection in FlatCam meas. domain ($Y_p$)

$$Y_p \cong P \cdot \hat{X}_p \cdot Q^T = P \cdot (\hat{X} - \hat{X}_s) \cdot Q^T$$
$$= Y - P \cdot \hat{X}_p \cdot Q^T = Y - Y_s$$

- Unify recovery & segmentation for visual privacy
  - Input/(output) is visually/(visually & privacy) protected
  - Assume attacker cannot extract intermediate features

→ *Resilient to transmission and encoder side attacks*

## 4. Performance Evaluation

- Reconstruction performance – PSNR (dB)

| Network | | Initial Recons. | | Enhance | |
|---|---|---|---|---|---|
| | | D-KConv | G-KConv | D-KConv | G-KConv |
| Set5 | Standard | 21.83 | 22.53 | 24.01 | 24.09 |
| | Residual | 22.53 | 22.63 | 24.17 | 24.04 |
| Set14 | Standard | 21.37 | 21.95 | 23.44 | 23.46 |
| | Residual | 21.36 | 22.05 | 23.55 | 24.41 |

*FlatCam[1]: Set 5 – 14.43 dB, Set14 – 13.89 dB*

- Evaluate the visual privacy protection quality via Facial Pixel Accuracy (FPA) & Intersection over Union (IoU)

| Network | | Initial Recons. | | Enhance | |
|---|---|---|---|---|---|
| | | D-KConv | G-KConv | D-KConv | G-KConv |
| FPA | Standard | 0.4090 | 0.9417 | 0.9386 | 0.9631 |
| | Residual | 0.4082 | 0.9427 | 0.9608 | 0.9646 |
| IoU | Standard | 0.3854 | 0.8521 | 0.8483 | 0.8678 |
| | Residual | 0.3847 | 0.8527 | 0.8678 | 0.8766 |

*Org/FlatCam[1]: FPA – 0.9340/0.6429, IoU – 0.8765/0.8765*

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