Privacy-Preserving Eye Videos using Rubber Sheet Model

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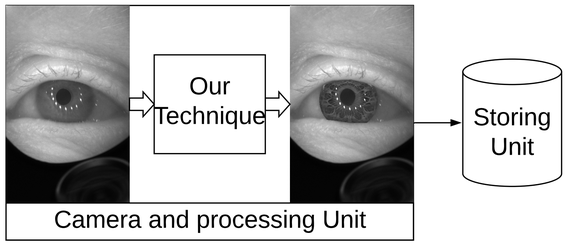
Overview

- **Eye data** contains **privacy-sensitive information**
- Need for **privacy regulations** and change in data capture/ process mechanisms to preserve privacy
- Prior work on eye video image manipulation:
  John et al. [proposed] **image defocus** (optical / digital blurring)
- Blurring image creates problem in methods relying on **pupil edge detection** or **iris feature based gaze estimation**

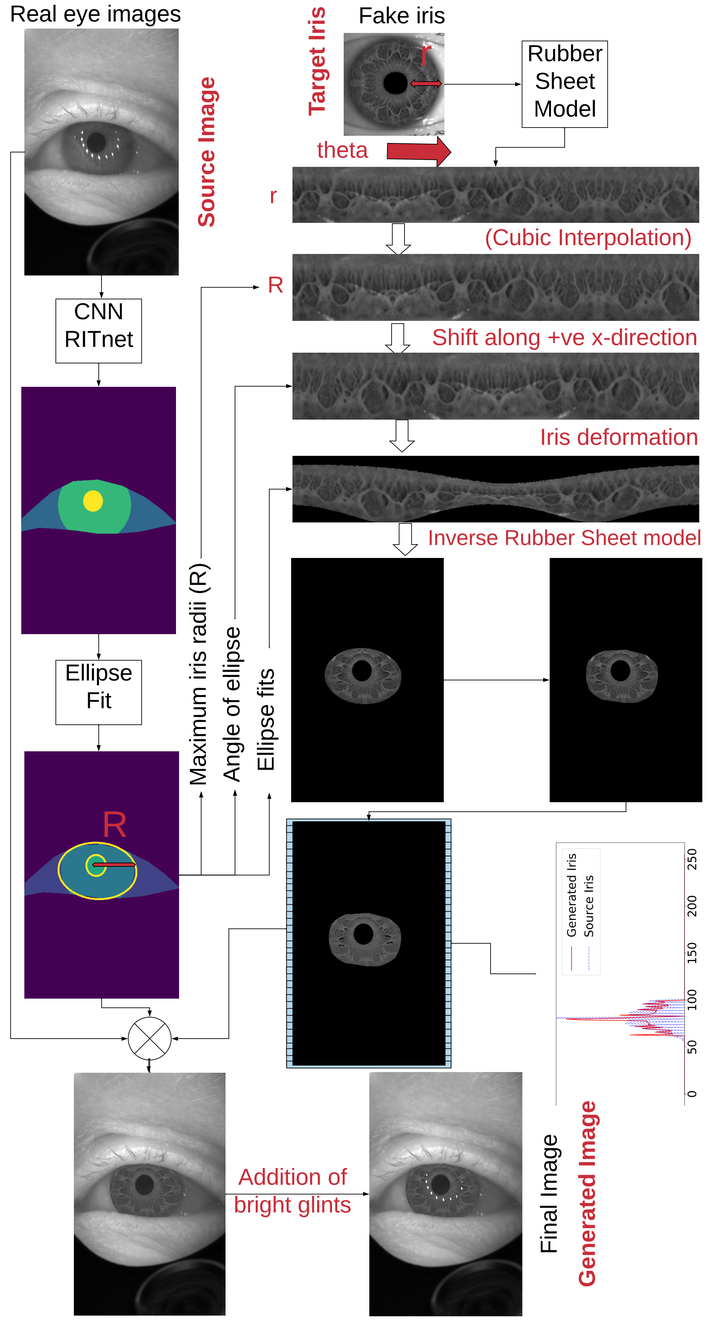
Proposed Method



- Tranformation technique based on **rubber sheet model** [Daugman, 1993]
- Rubber sheet model transforms every point in **Cartesian coordinate system** to a rectangular approximation of its **polar coordinate system**
- **Eye Segmentation:** to identify iris region (e.g. RITnet)
- **Iris Transformation:** handle cases of texture warp, iris deformation, & histogram equalization to match real eye images
- **Glints positions** are important for some eye tracking methods
- **Blended Image:** weighted average of generated and real eye images

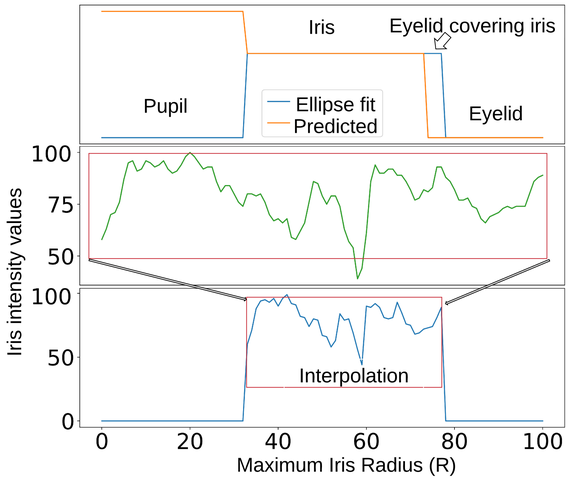
References

Brendan John, Sanjeev Koppal, and Eakta Jain. 2019. EyeVEIL: degrading iris authenti- cation in eye tracking headsets. In Proceedings of the 11th ACM Symposium on Eye Tracking Research & Applications. 1–5.
John G Daugman. 1993. High confidence visual recognition of persons by a test of statistical independence. IEEE transactions on pattern analysis and machine intelligence
A. K. Chaudhary, R. Kothari, M. Acharya, S. Dangi, N. Nair, R. Bailey, C. Kanan, G. Diaz, and J. B. Pelz. 2019. RITnet: Real-time Semantic Segmentation of the Eye for Gaze Tracking. In 2019 IEEE/CVF International Conference on Computer Vision Workshop (ICCVW).
Stephan J Garbin, Yiru Shen, Immo Schuetz, Robert Cavin, Gregory Hughes, and Sachin S



Basic flow of proposed method. The source image is passed to a CNN to annotate the eye regions. The target iris undergoes a rubber sheet model transformation followed by other transformations based on the information from the source image. This results in a generated iris similar to the source iris shape, which is then mixed with the source image to get the final image after the glints are replaced.

Iris Deformation

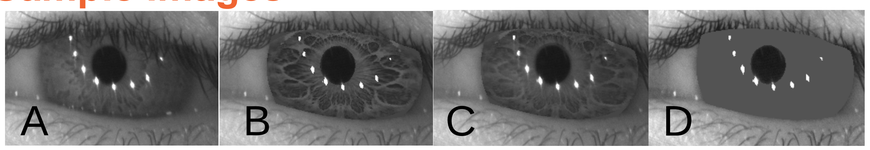


(Top) The annotated labels for one radial angle. As we move from the center of the iris to the maximum iris radius (R), we encounter pixels representing pupil, iris, and sclera/eyelid regions.

(Middle) The generated texture along that radial angle.

(Bottom) After interpolation of the textured pattern, it only covers the desired iris as seen in (Top). Note that some iris features are invisible under the eyelids.

Sample Images



Source | Generated | Blended | Median

Results

- Segmentation performance (mean IoU) within 3% of original
- MSE in pupil center within 0.47 pixels
- Small improvement in pupil detection rate
- Hamming distance: 0.47 from original source image

Future Work

- Use of **Generative Adversarial Network**
  => to create unidentifiable iris
- Account for other eye features that contain privacy data:
  => **sclera, eye corners, eyelids, facial structure, and even eye movements**

Our Presence at ETRA 2021

- Enhancing the precision of remote eye-tracking using iris velocity estimation (Short Paper)
- Semi-Supervised Learning for Eye Image Segmentation (Short Paper)
- RIT-Eyes, realistically rendered eye images for eyetracking applications (Video)