USING INFRARED ILLUMINATION TO IMPROVE EYE & FACE TRACKING IN LOW QUALITY VIDEO IMAGES

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Outline

- Introduction
  - Problem definition
- The algorithm
  - Face detection
  - Eye detection
  - Eye and face tracking
- Results
- Concluding Remarks

Experimental variables
(Low resolution images)

- The setup consists of a single black and white camera sensitive to the wavelength of the infrared light.

- A standard 60W bulb is used to adjust the overall illumination of the room

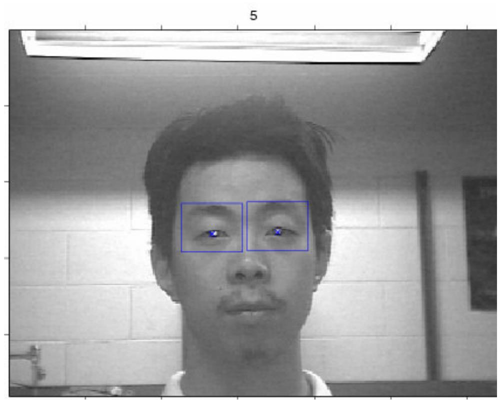
Cont'd

- The volunteer is placed at 1.5 m from camera
- Pose: 0^o, 15^o, 30^o, 45^o
- Subjects with and without glasses
- Different types of eye colors
- Differing levels of skin tone

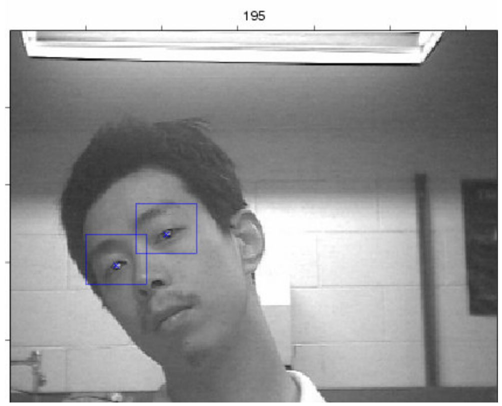
Contributions

- Work achieved:
  - Face and eye detection in low quality images using low IR illumination
- Possible applications:
  - Improving surveillance in poor illumination for face detection
  - Increase accuracy of eye detection in modern surveillance applications especially in situations with variable lighting, and when dealing with low resolution images.

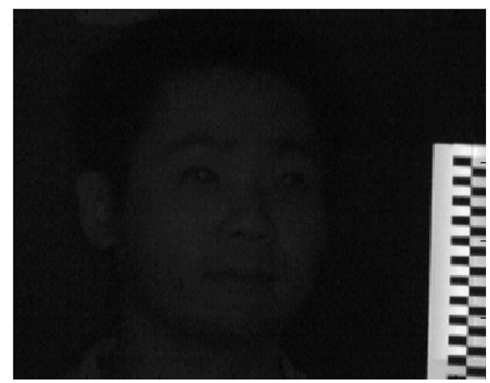
Original images



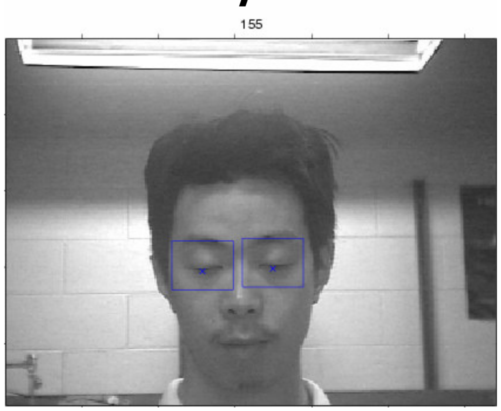
Initial position

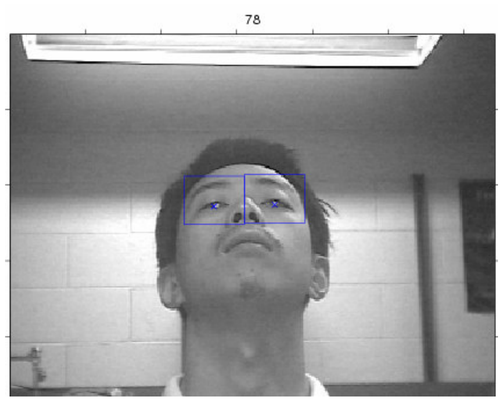


Head tilted



Low resolution





Closed eyes

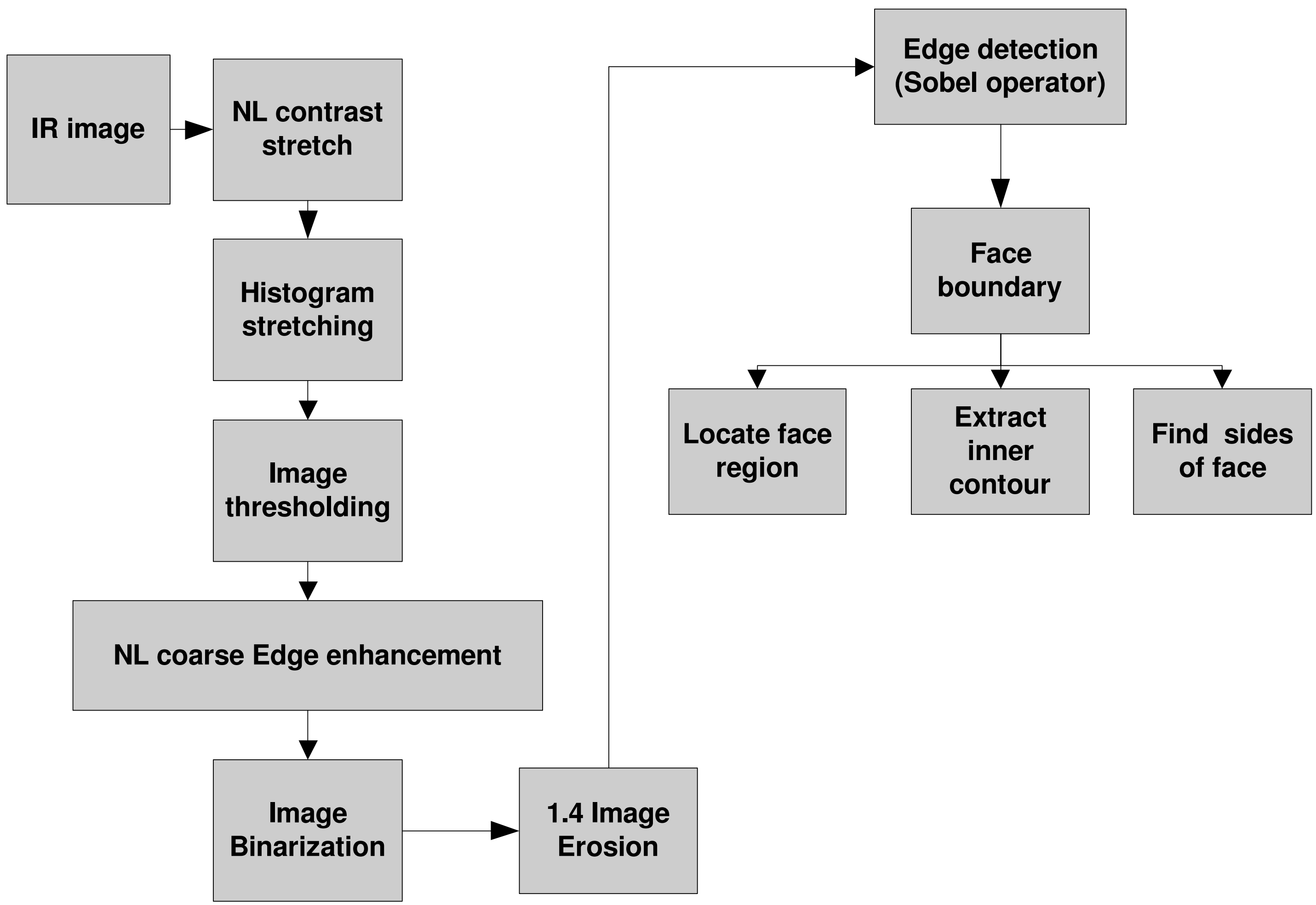
ISL Database

Algorithm Design: Step 1

Initial face detection

Algorithm design

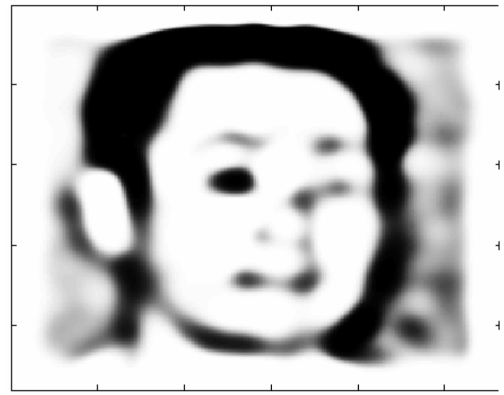
Step 1: Face boundary



Example of initial face detection in low resolution images

Original image

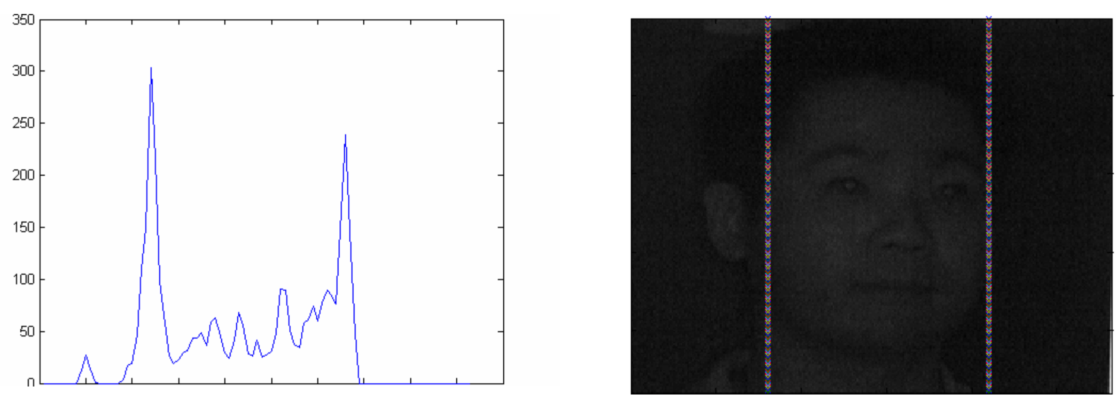
NL contrast stretch



NL coarse edge enhancement

Edge detection

Inner contour extraction

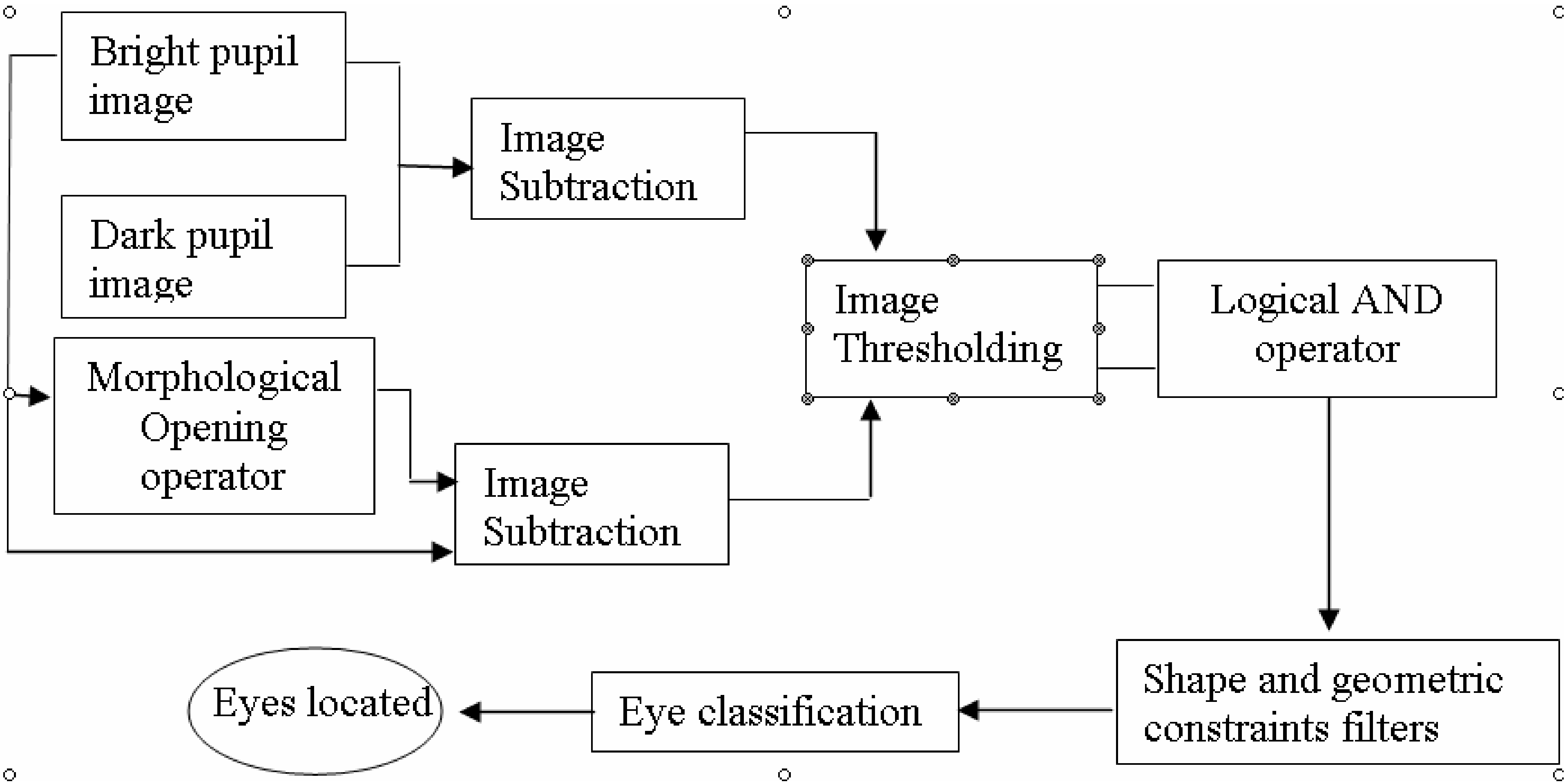


Locate face boundary

Algorithm Design: Step 2

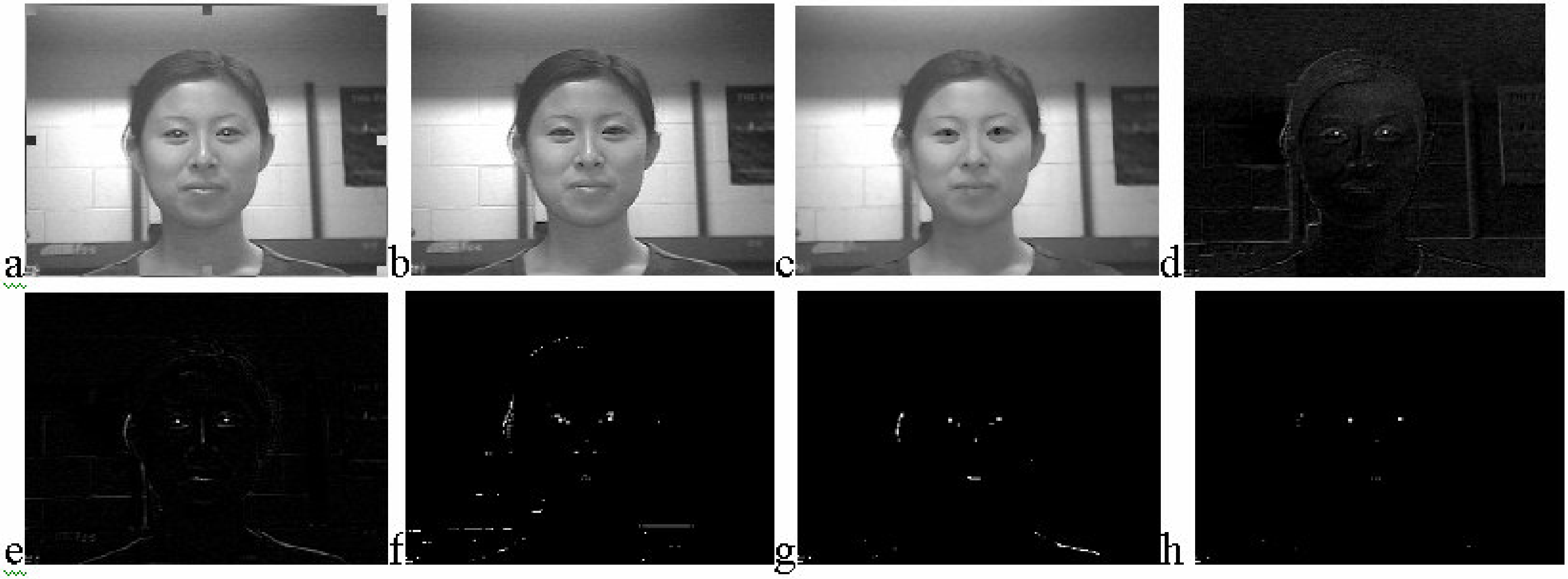
Initial eye detection

Algorithm



Bright pupil image
Dark pupil image
Image Subtraction
Morphological Opening operator
Image Subtraction
Image Thresholding
Logical AND operator
Shape and geometric constraints filters
Eye classification
Eyes located

Example of initial eye detection and image differencing



(a) Bright pupil image, (b) dark pupil image, (c) image obtained after morphological opening with a disk structure of size 2, (d) [a-b], (e) [a-c],

(f), (g) Thresholded images using a very small threshold to account for most reflections in the image,

(h) Image obtained using the logical AND operator which keeps the bright regions which appear in both thresholded images.

Algorithm Design: Step 3

Eye & Face tracking

Algorithm design includes:

- Template correlation
- Face and eye detection using previous template
- Pupil candidate regions computation and eye tracking
- Kalman filtering
- Eye contour extraction

I. Template correlation

- Two eye templates are created for matching from the initial eye detection step.
- The templates size is chosen to be 40x40
- Templates are updated after each frame using the previously computed pupil positions.
- The correlation scores are then calculated for every frame using the normalized correlation coefficient

$$C = \frac{\sum_{x,y}\left[f(x,y)-\bar{f}_{u,v}\right]\left[t(x-u,y-v)-\bar{t}\right]}{\sqrt{\sum_{x,y}\left[f(x,y)-\bar{f}_{u,v}\right]^2 \sum_{x,y}\left[t(x-u,y-v)-\bar{t}\right]^2}}$$

II. Pupil candidate regions computation and eye tracking

- ***Step 1***: Compute the centroid of all the connected regions in the binary image obtained using connected component analysis.
- ***Step 2***: Eliminate all regions with centroids located outside the face contour previusly computed.
- ***Step 3***: Find the region that has the closest centroid to the prior eye location computed in images at instance *t-1*.
- ***Step 4*****:** After detecting possible pupil candidates, the kalman filter is then used to compute the exact location of the bright pupil in the difference image.
- ***Step 5***: After computing the pupil coordinates, update the eye and face templates to process the successive frames.
- **Step 6**: Extract eye region

Experimental results

Database	Subjects	# of images per subject	Total processed images	Detection and tracking results
ISL EYE IR	4	300	1200	1200/1200
Underexposed low quality images	3	200	600	591/600

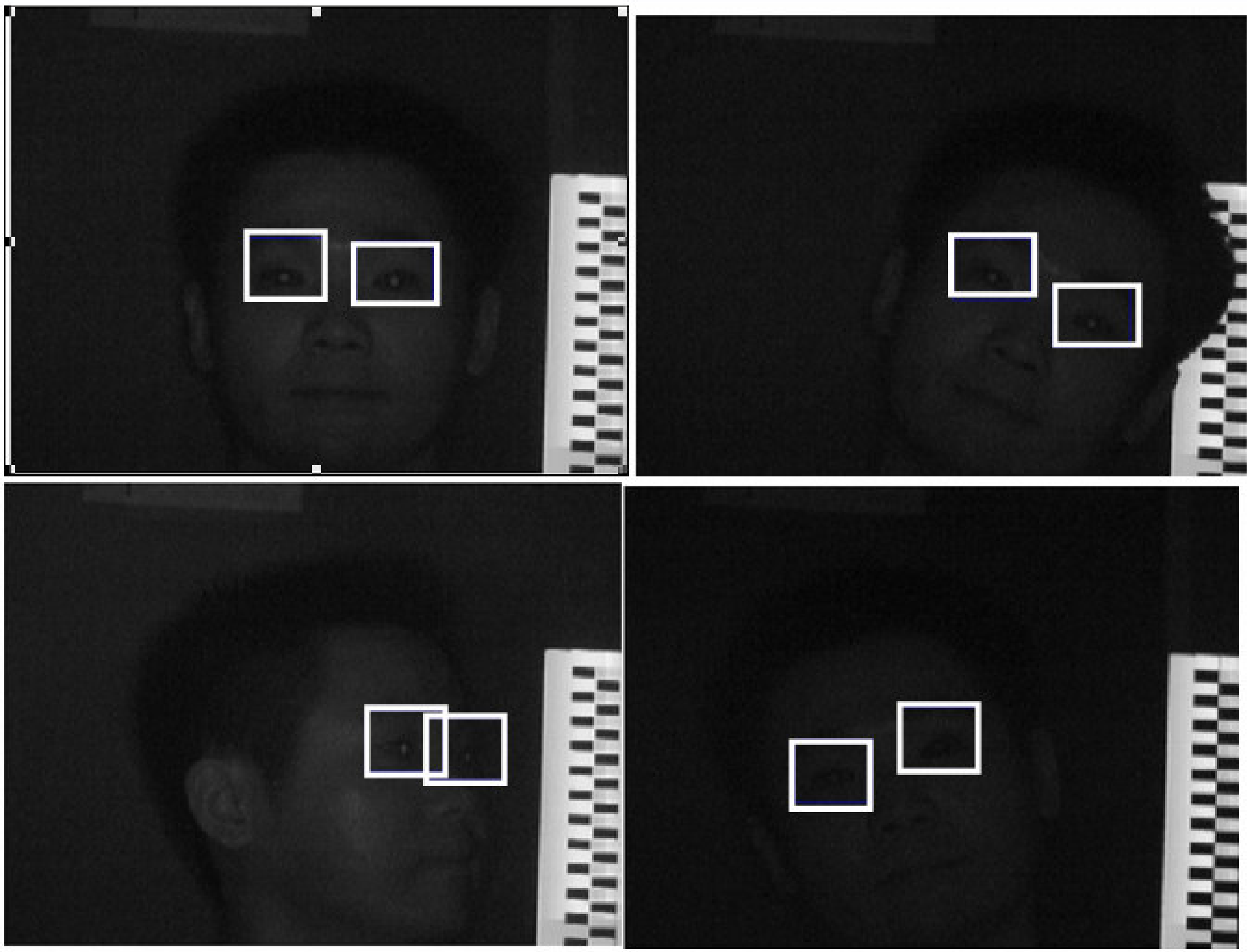
Table showing eye detection and tracking results. 1800 images are processed in total using two different IR image databases

Detection offset error

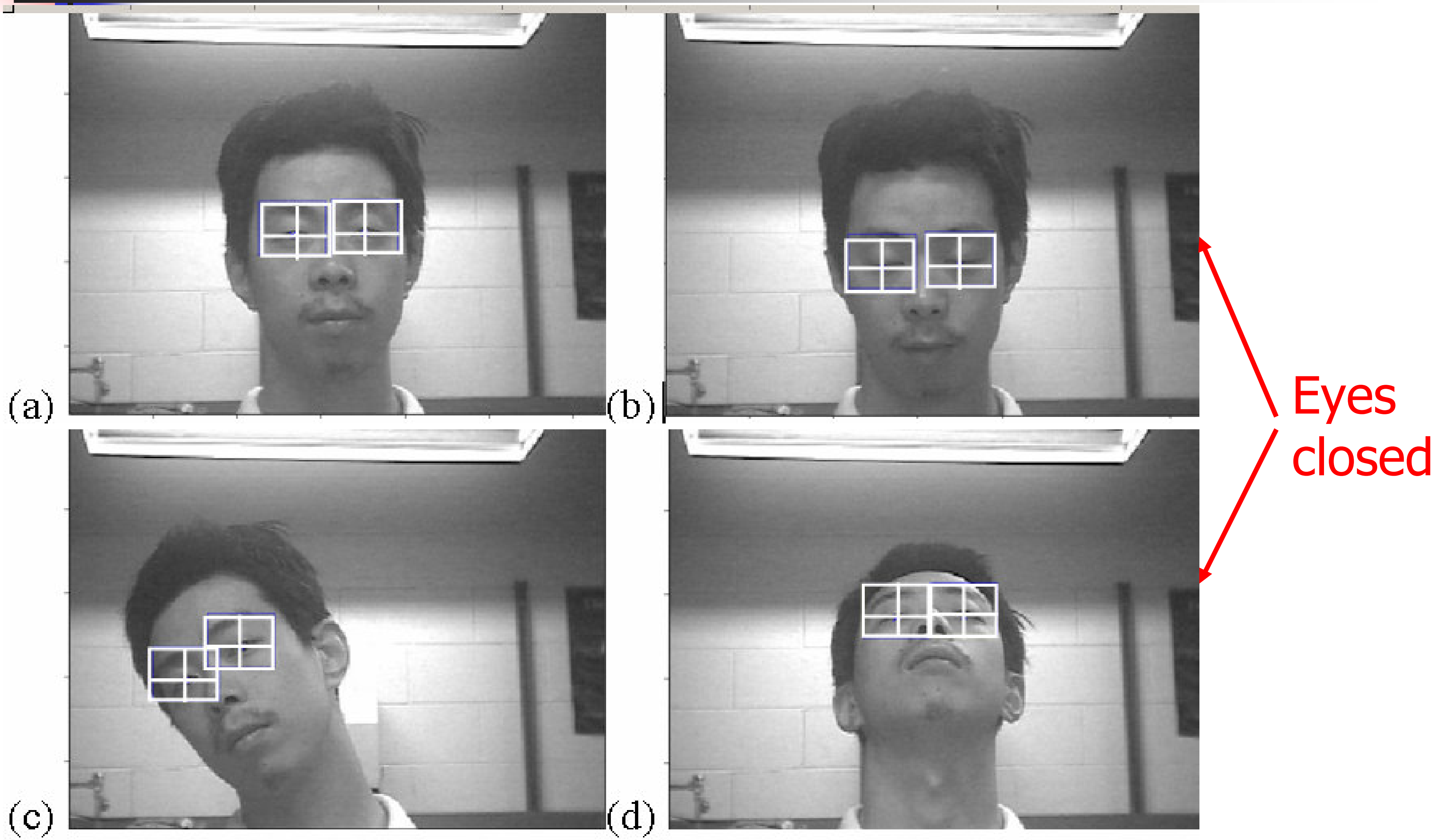
Database	μ_{error} in pixels (hor-direction)	σ_{error} in pixels (hor-direction)	μ_{error} in pixels (vert-direction)	σ_{error} in pixels (vert-direction)
ISL: 1200 frames	1.0976	0.9090	2.2352	1.9794
Low quality: 600 frames	1.4402	1.3297	3.0829	1.9628

Table showing average pixel offset error and standard deviation results for eye detection in the horizontal and vertical directions. μerror is average pixel offset error and σerror is the standard deviation of the offset error, respectively.

Eye detection results in low resolution images



Eye detection (ISL database)



Conclusion

- This paper presents a new algorithm to extract and track face and eye positions from surveillance type images with IR strobe taken under poor illumination.

- In the case where many reflections (blobs) occur, the algorithm will find all possible eye locations and presents the best solution using multi-stage classification techniques.

Conclusion (cont’d)

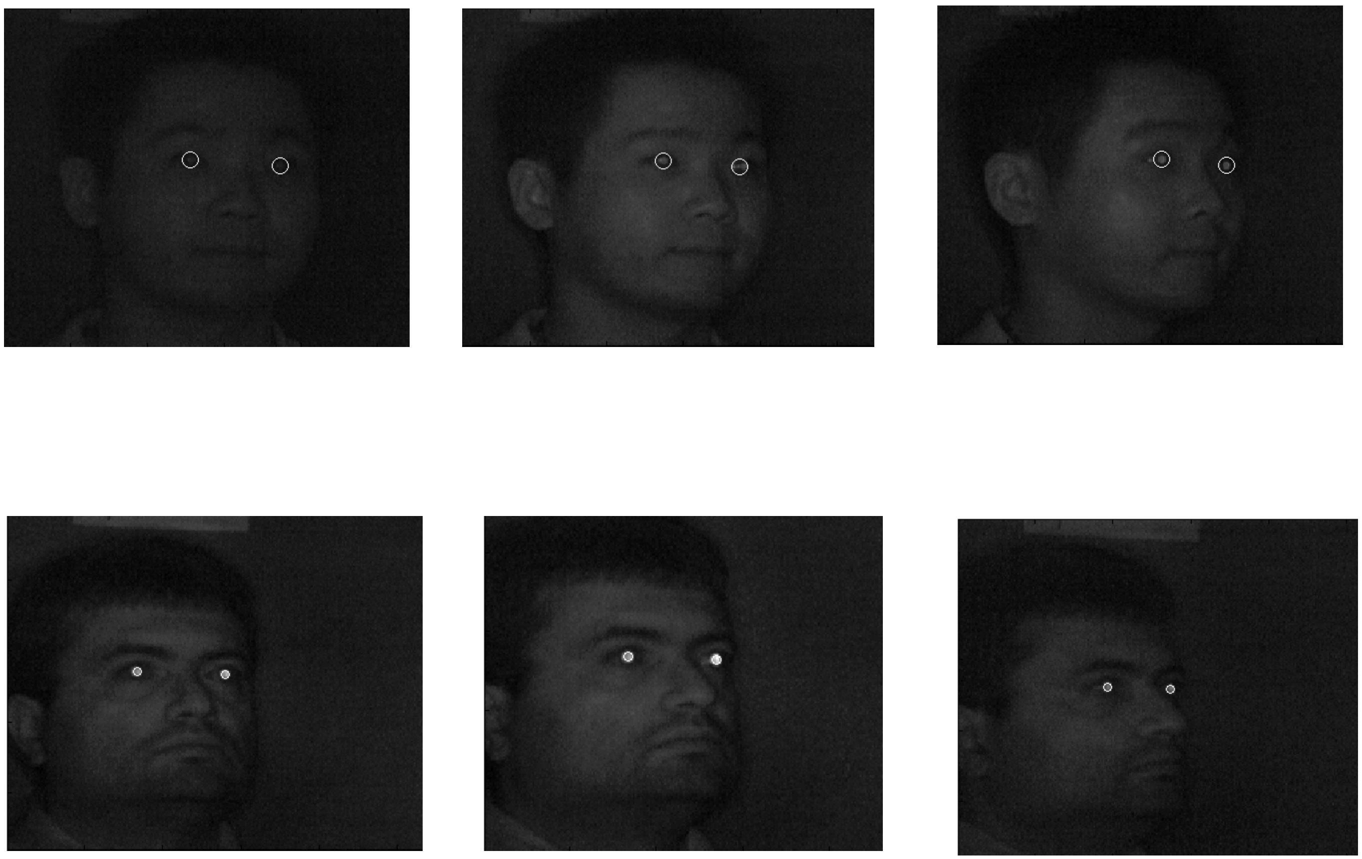
- A kalman tracker is used to approximate eye location in bright pupil images. This improves the performance and accuracy of the system when dealing with faces at different orientation and with eye closure.
- The algorithm achieves a 99.5% detection rate using 1800 images taken from two different IR image databases

Thank you

References

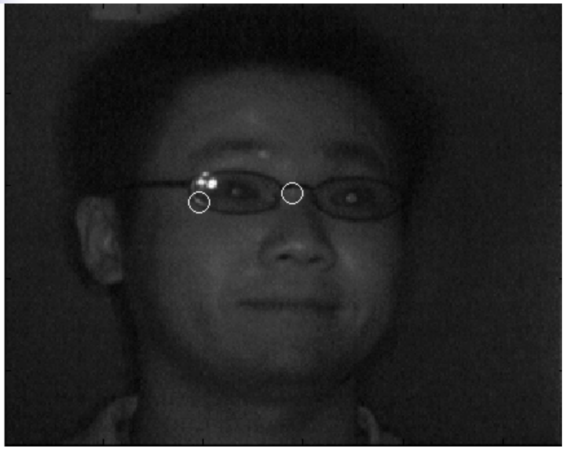
- Asfaw, Y., Chen, B., Adler, A.,"Face detection using red-eye effect", Department of Electrical engineering, University of Ottawa, Canada, 2002.
- Chau, M., Betke, M., "Real time eye tracking and blink detection with USB cameras", Technical Report, Boston University Computer Science, 2005.
- Comaniciu,D., Ramesh, V., Meer, P., "Real-time tracking of non-rigid objects using mean shift", *in: IEEE Conf. on Computer Vision and Pattern Recognition*, Hilton Head Island, South Carolina, 2000.
- Deng, G., Cahill, L.W., "Multiscale image enhancement using the logarithmic image processing model", Electronics Letters, 29:803-804, 1993.
- Deng, G., Cahill, L.W., "Image Enhancement Using the Log-ratio Approach", Signals Systems and Computers, 1:198-202, 1994.

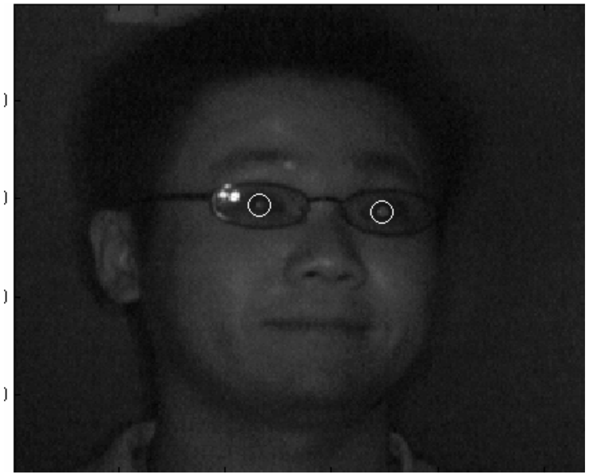
Results: No glasses



15°   30°   45°

Results: With glasses



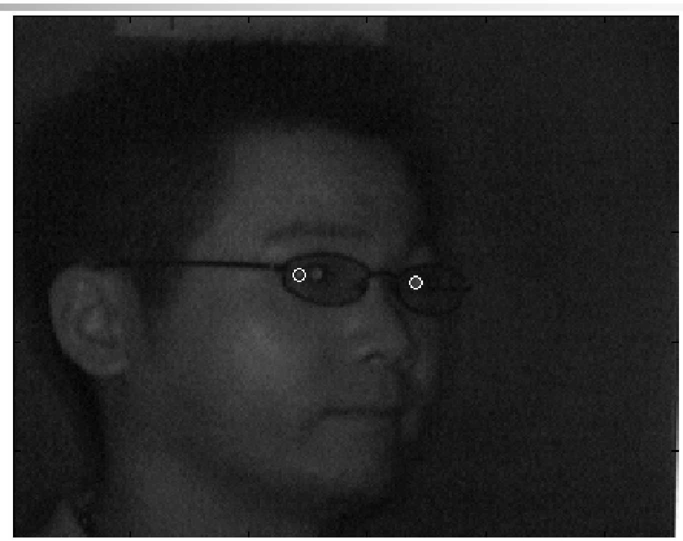


15°

Results: With glasses

30°

Results: With glasses



45^o