Perspective Projection

97° FOV (19mm)

Perspective Projection

97° FOV (19mm)

Preview: Our Result

97° FOV (19mm)

Preview: Our Result

97° FOV (19mm)

Motivation

- Perspective projection makes **unnatural look** on faces near image corners.

- **Portrait** is important to photography.
  - 44% of photos contains faces.
  - E.g., selfie, group portraits, group, etc.


Group Selfie Cam
Google Pixel 3

Trend: Wide-angle Camera are GROWING!

Make	Samsung	Google	Asus	Huawei	LG	OnePlus	Sony	Xiaomi
Flagship Model (2019)	S10 plus	Pixel 3	Zenfone 6	P30 Pro	V50 Thin Q	7 Pro	Xperia 1	Mi9
Field-of-view (FOV)	**123°**	**97°**	**125°**	**107°**	**107°**	**117°**	**130°**	**104°**
35mm equiv. focal length	12mm	19mm	11mm	16mm	16mm	13mm	10mm	17mm

- Human vision (FOV/35mm-equiv): **60°**/37.5mm

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- Human vision (FOV/35mm-equiv): **60°/**37.5mm
- Major camera phone prior to 2018 (FOV/35mm-equiv): **80°**/26mm

NOT A Lens Distortion

Lens distorted image

NOT A Lens Distortion

Lens distorted image

Corrected image (perspective projection)

Goal: Distortion-Free Wide-angle Portraits

- Makes faces look **natural** even large at field-of-view (FOV).
  - As if faces are captured from the camera center.
  - Robust to face poses, facial expressions, and occlusions.

Goal: Distortion-Free Wide-angle Portraits

- Makes faces look **natural** at large field-of-view (FOV).
  - As if faces are captured from the camera center.
  - Robust to face poses, facial expressions, and occlusions.

- Works for mobile platform.
  - **Automatic** correction without user intervention.
  - Efficient processing to achieve interactive rate.

Related Work: Global Projection

Perspective Projection

Stereographic Projection

Mercator Projection

Related Work: Content-aware Warping

- Spatially-variant radial correction [Zorin and Barr 1995].

Input

Output

Related Work: Content-aware Warping

- Optimizing global conformality [Carroll et al. 2009].

Input

[Carroll et al. 2009]

Related Work: Content-aware Warping

- Optimizing global conformality [Carroll et al. 2009].
- Selects a different virtual camera viewpoint [Tehrani et al. 2016].

Input

[Carroll et al. 2009]

Input

[Tehrani et al. 2016]

Related Work: Perspective-aware Warping

- Corrects foreshortening [Fried et al. 2016]

Input

Output

Our Idea: *Local* Stereographic Projection on Faces

Perspective projection
- Face is stretched ☹
- Background looks good ☺

Stereographic projection
- Face looks natural ☺
- Background is distorted ☹

Our result by local warp
- Face look natural ☺
- Background look good ☺

Algorithm Overview

Input (perspective projection)

Algorithm Overview

Subject segmentation using CNN
[Wadhwa et al. 2018]

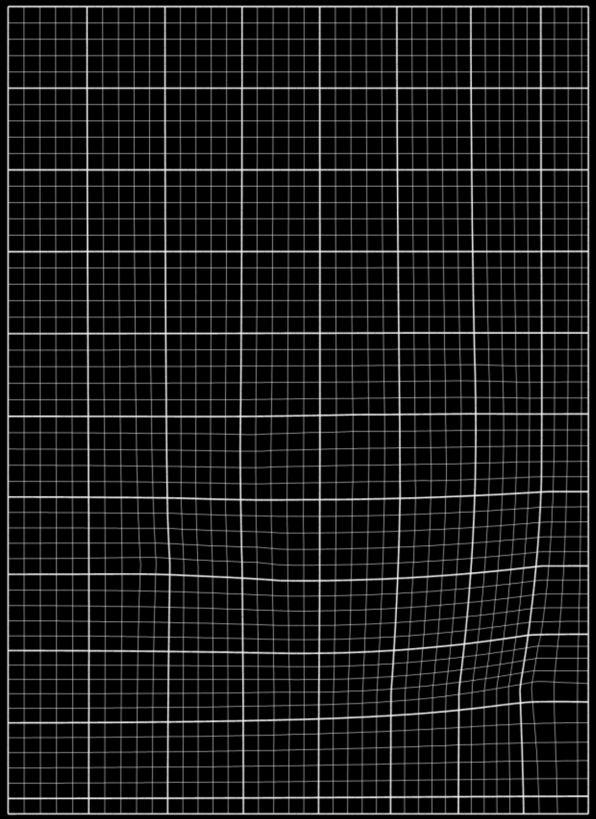
Algorithm Overview

Face detector for face region

Algorithm Overview

Input (perspective projection)

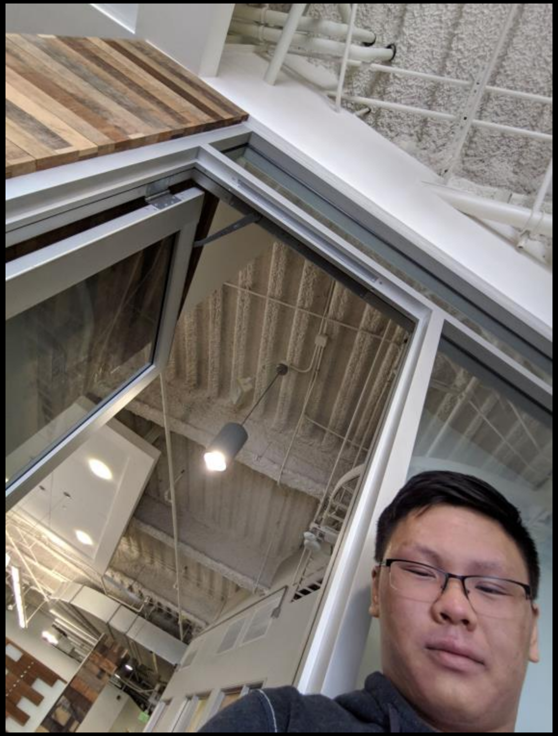
Stereographic projection



Mesh optimization

Output by warping

Naïve Mesh Blending

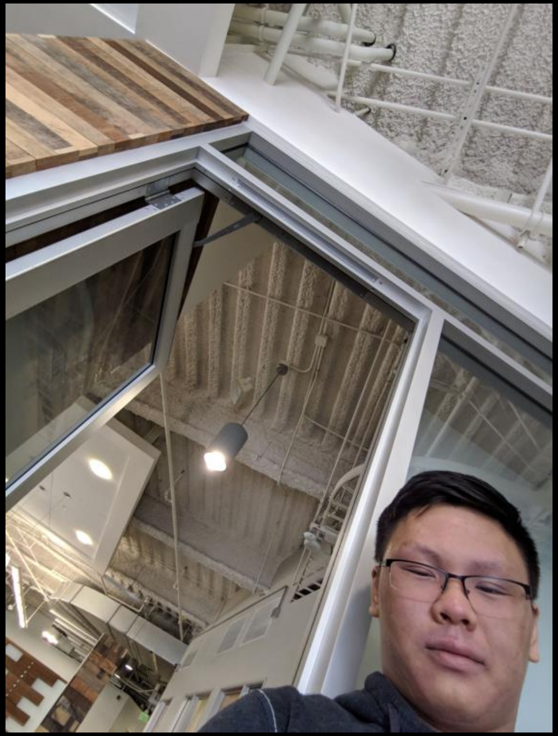


(a) Input (97° FOV)

Inset of (a)

Naïve mesh blending

Naïve Mesh Blending



(a) Input (97° FOV)

Inset of (a)

Naïve mesh blending

Optimized mesh warp

Mesh Optimization

- Defines an energy function over the vertices on the mesh.

$$\{\mathbf{v}_i^*\} = \underset{\{\mathbf{v}_i\}}{\operatorname{argmin}} E_t(\{\mathbf{v}_i\}),$$

Face Objective Term

- Each detected face k associates with a face term $E_{s,k}$,

$$E_f = \sum_k E_{s,k},$$

stereographic projection vertices.

$$E_{s,k} = \sum_{i \in \mathbf{B}_k} w_i m_i \|\mathbf{v}_i - (\mathbf{S}_k \mathbf{u}_i + \mathbf{t}_k)\|_2^2 + \lambda(\mathbf{S}_k),$$

face weight; 1/0 for face/non-face region using segmentation.

Face Objective Term

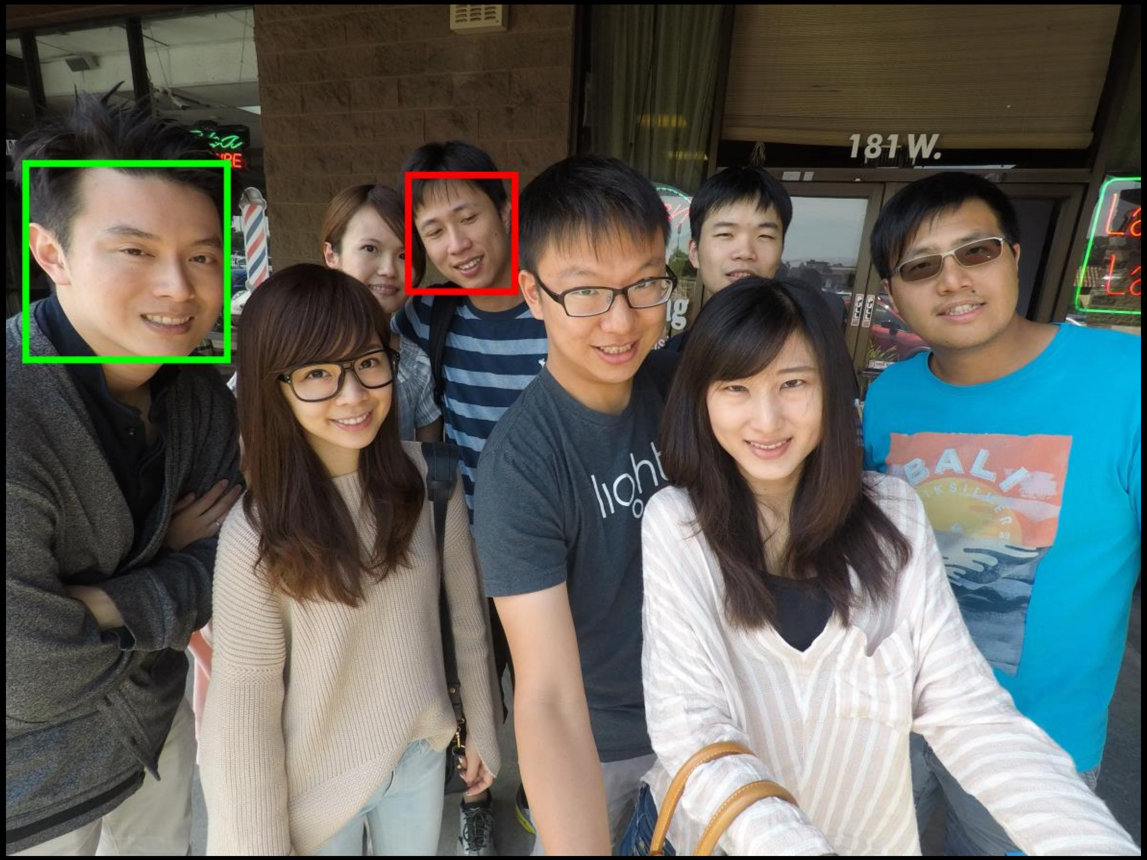
$$(1 + \exp(-(r - r_a)/r_b))^{-1}$$

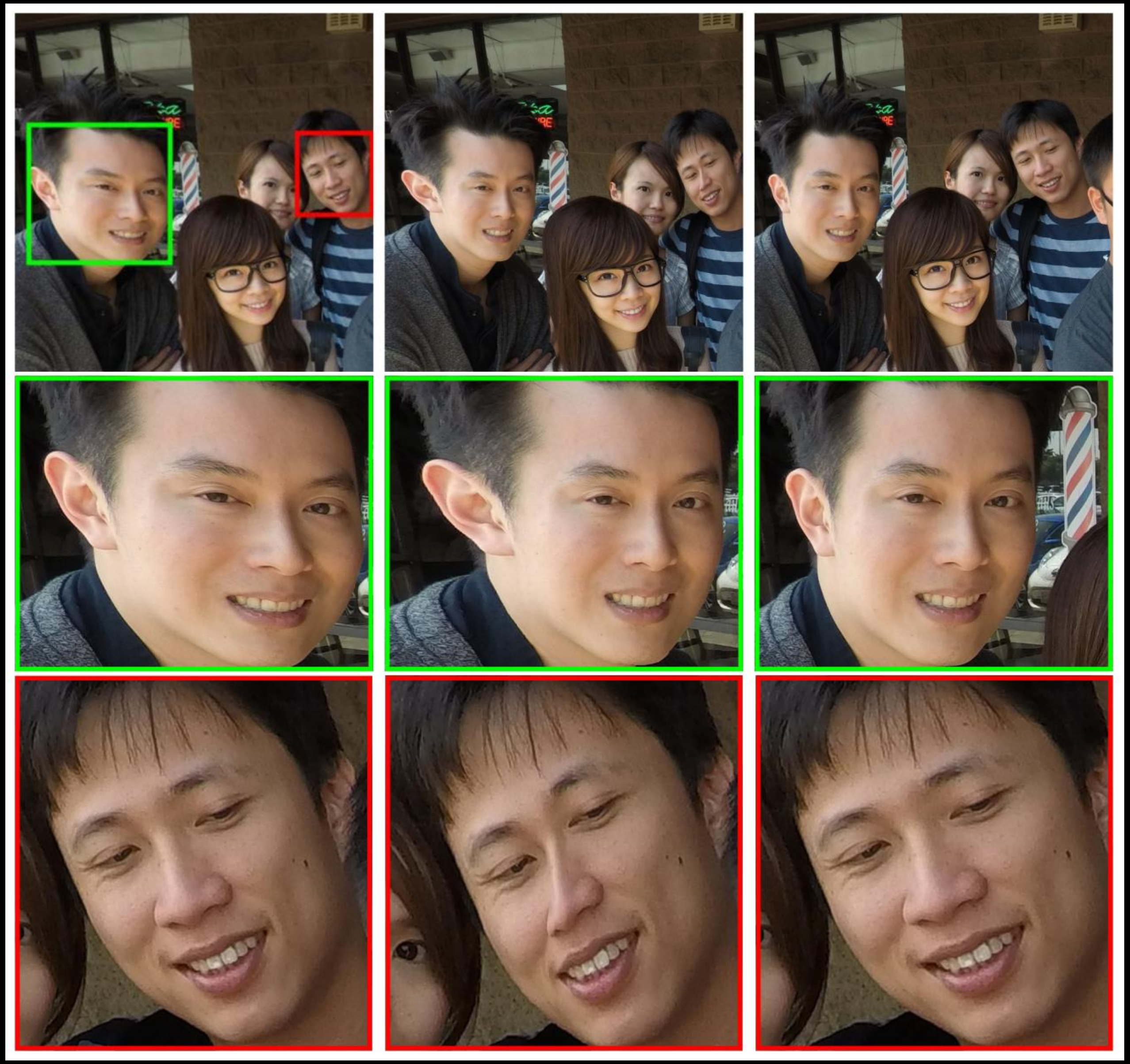
$$\lambda(\mathbf{S}_k) = w_s \|a_k - s_t\|_2^2 ,$$

$$E_{s,k} = \sum_{i \in \mathbf{B}_k} w_i m_i \|\mathbf{v}_i - (\mathbf{S}_k \mathbf{u}_i + \mathbf{t}_k)\|_2^2 + \lambda(\mathbf{S}_k) ,$$

$$\mathbf{S}_k = \begin{bmatrix} a_k & b_k \\ -b_k & a_k \end{bmatrix}$$

Benefits of Face Term

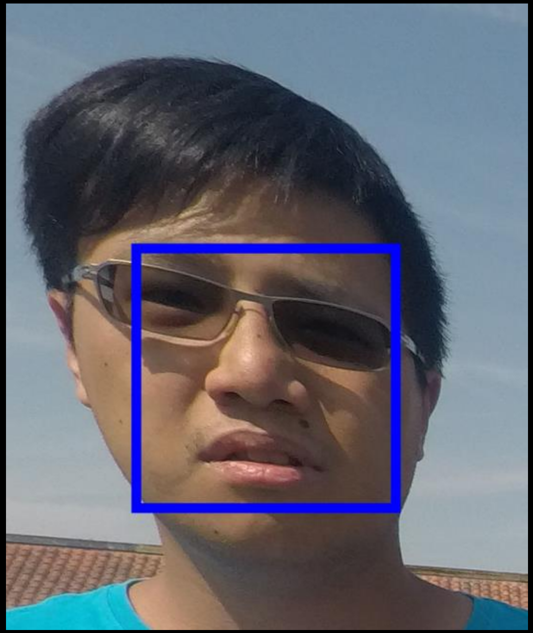




Input Without ***S, t*** Our method

Benefits of Subject Mask

(a) Input and mask



Inset of (a)

Without mask

Our method

Line Bending Terms

$$E_b = \sum_i \sum_{j \in N(i)} \|(\mathbf{v}_i - \mathbf{v}_j) \times \mathbf{e}_{ij}\|_2^2$$

$$E_r = \sum_i \sum_{j \in N(i)} \|\mathbf{v}_i - \mathbf{v}_j\|_2^2 \, .$$

(a) Input

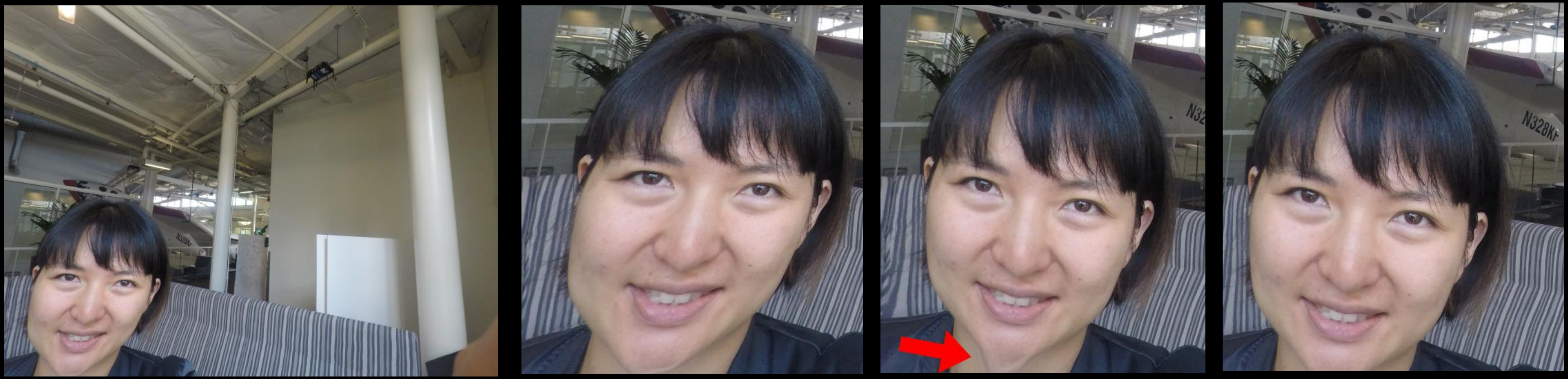
Inset of (a)

Without line bending term

Our method

Mesh Boundary Padding

- Relax boundary by padding additional vertices.



(a) Input | Inset of (a) | Without padding | Our method

Mesh Optimization

- Total energy cost by summing up
  - Face term
  - Line bending term
  - Regularization term
  - Boundary conditions
- Solves the linear energy function with Ceres.

Handling Lens Distortion

- Combines the optimal mesh with lens undistortion warp.

(a) Lens undistorted input

Our method by warping (a)

Results

- 167 photos from Flickr.

- FOVs range from 70° -120°.

- Various features:
  - Different genders, ages, facial expressions, lighting conditions.
  - Glasses, hair styles, accessories.

- Available on our project website.

Input

97°FOV
Pixel 3

Output

Input

104°FOV

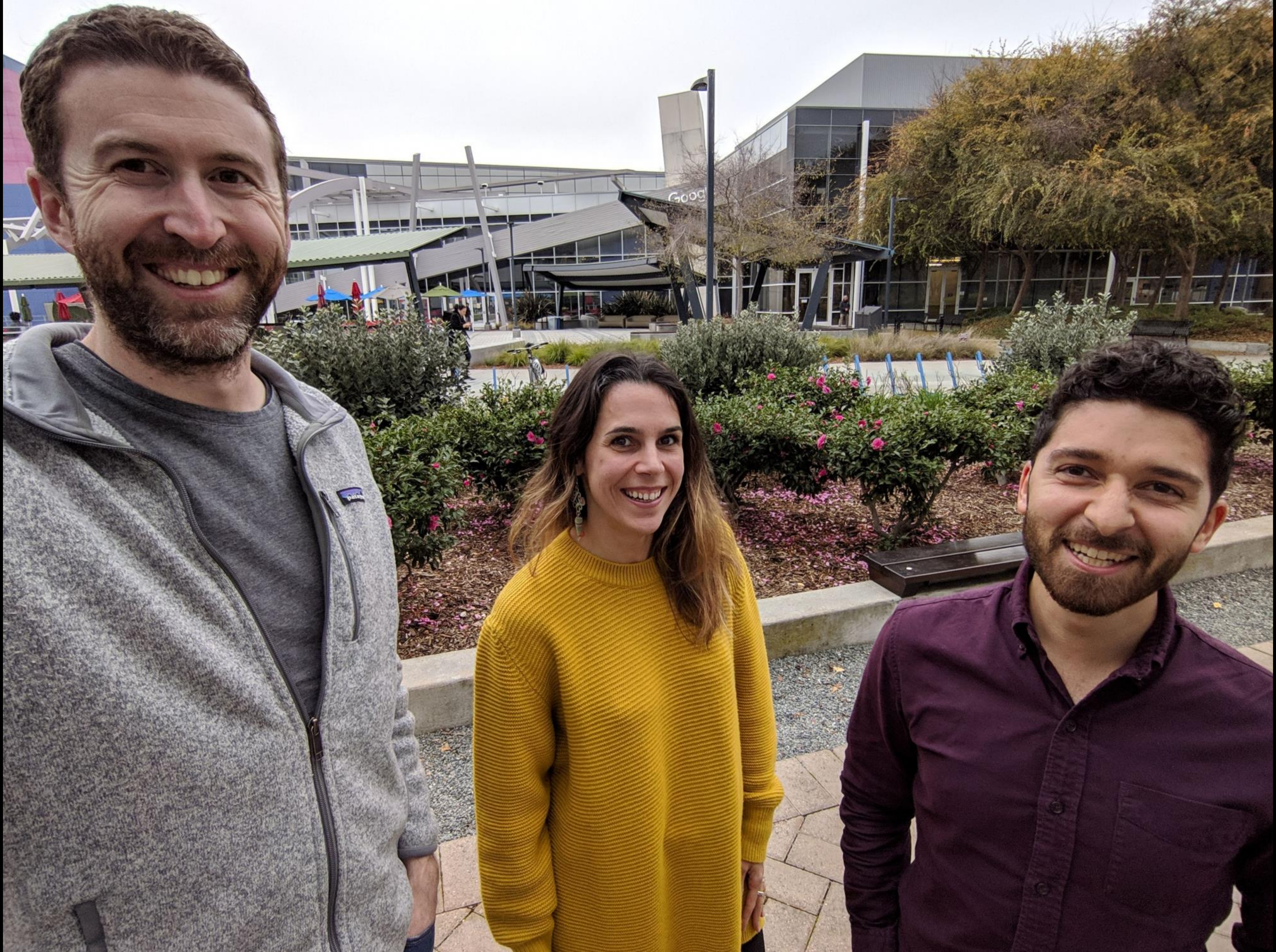
DSLR

Output

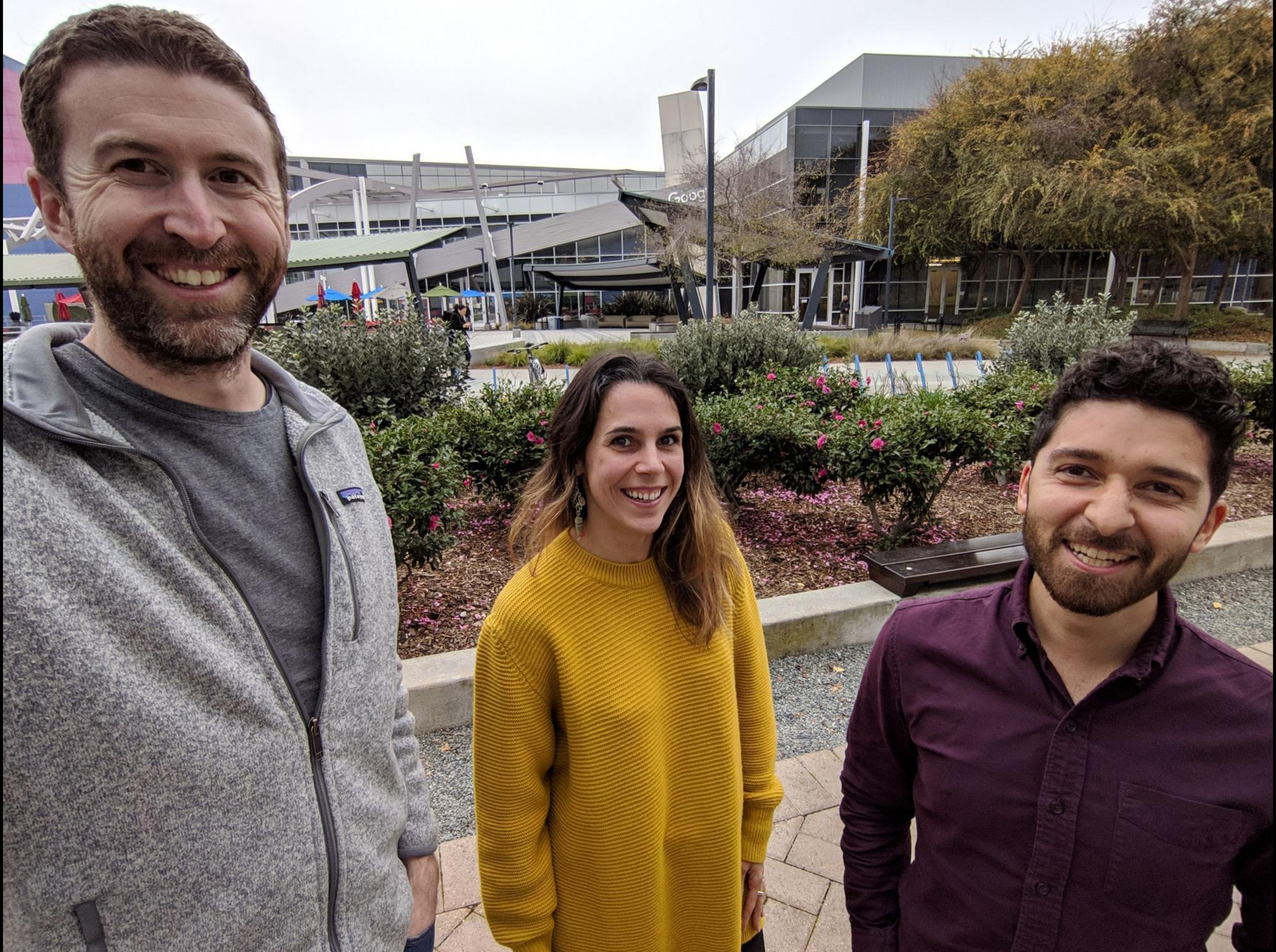
Input

97°FOV

Pixel 3



Output

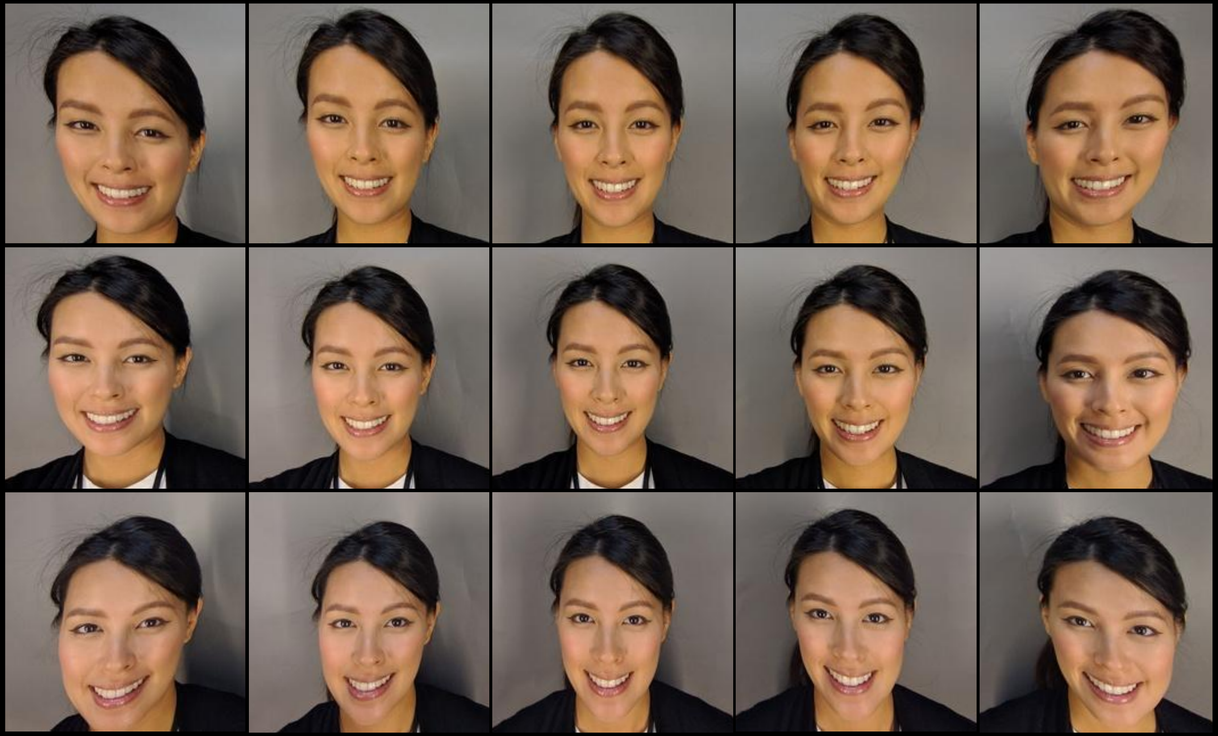



Input
97°FOV (Pixel 3)

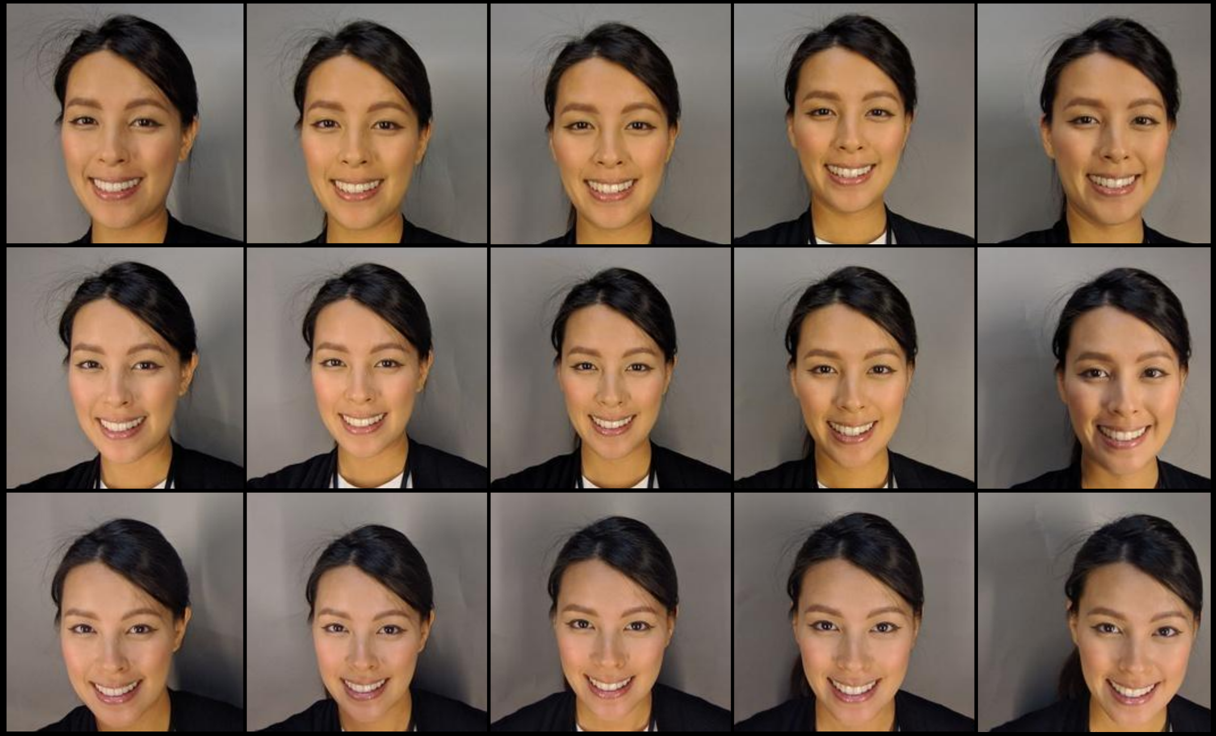

Output

Correction at Various FOVs

- Subjects at a 5x3 grid over a 97°FOV camera.



Input



Output

Normal
FOV

Input 80°FOV

Normal FOV

Output

Large Group

Input 80°FOV

Large Group

Output

Input

Output

Stress Test

Input 103°FOV
(GoPro Hereo5)

Stress Test

Output

Occlusion

Input <u>103°FOV</u>

Occlusion

Output

Comparisons

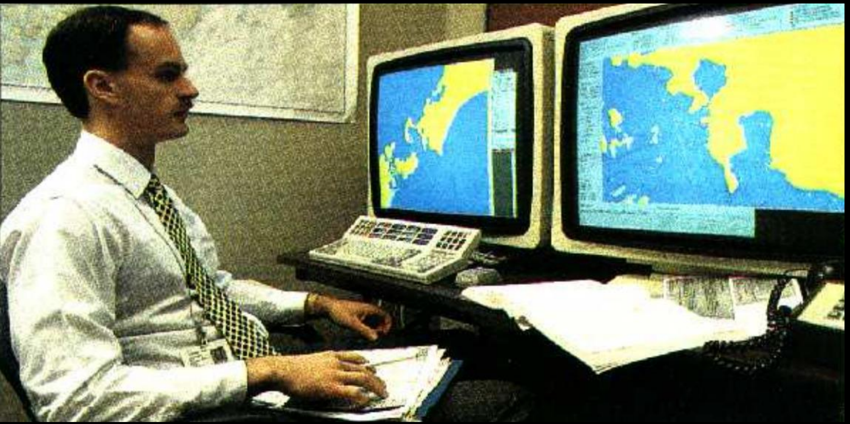
Input (100° FOV)

Pannini
[Sharpless et al. 2010]

Adobe Photoshop
Perspective Warp

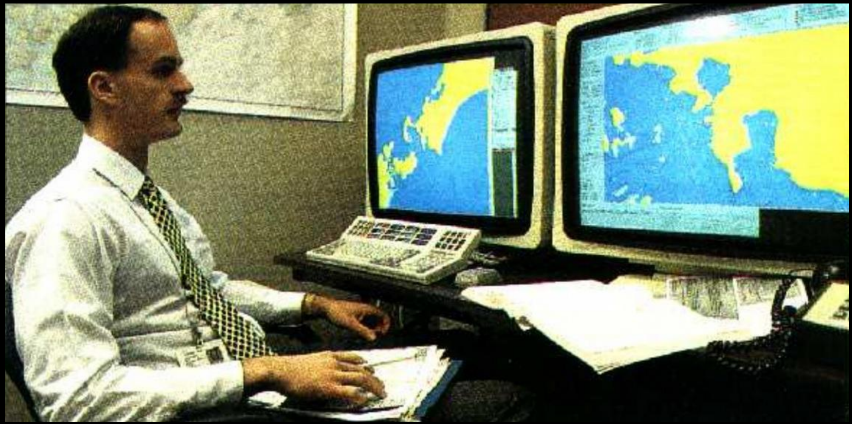
Our method

Comparisons



Input (92° FOV)

[Zorin and Barr 1995]



Our method

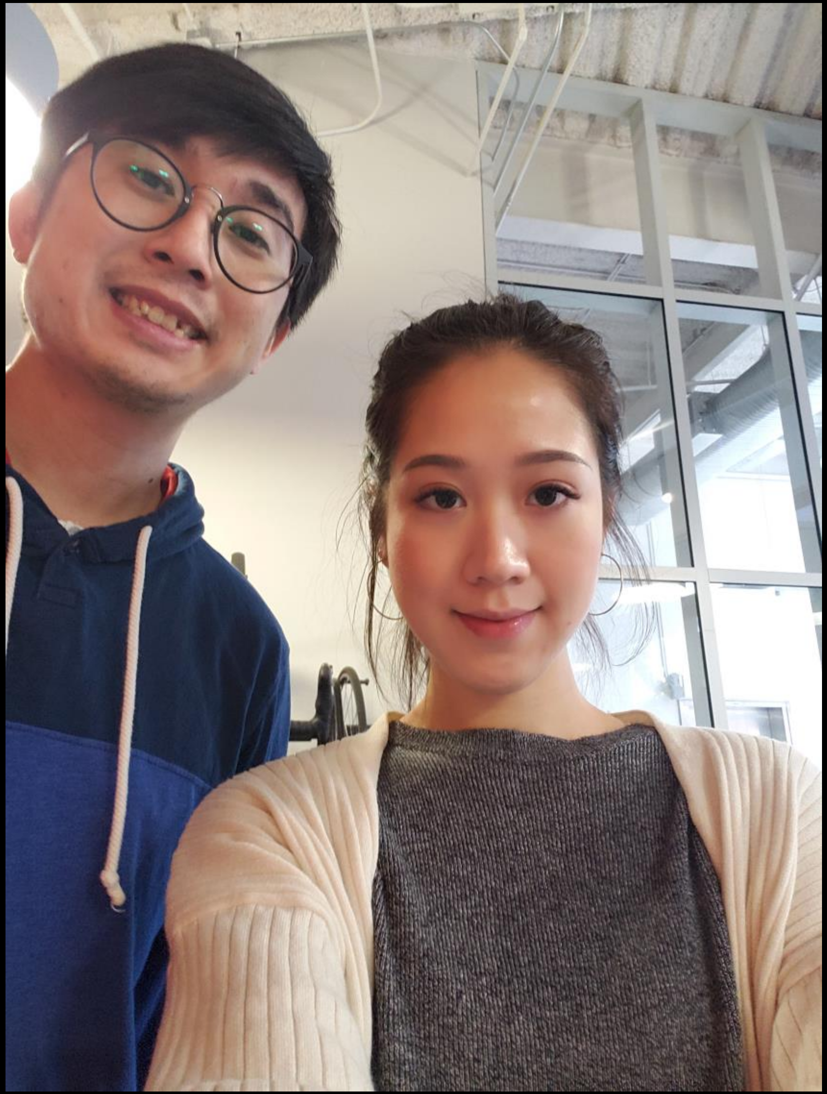
Comparisons: DxO Viewpoint3

Input (97° FOV)

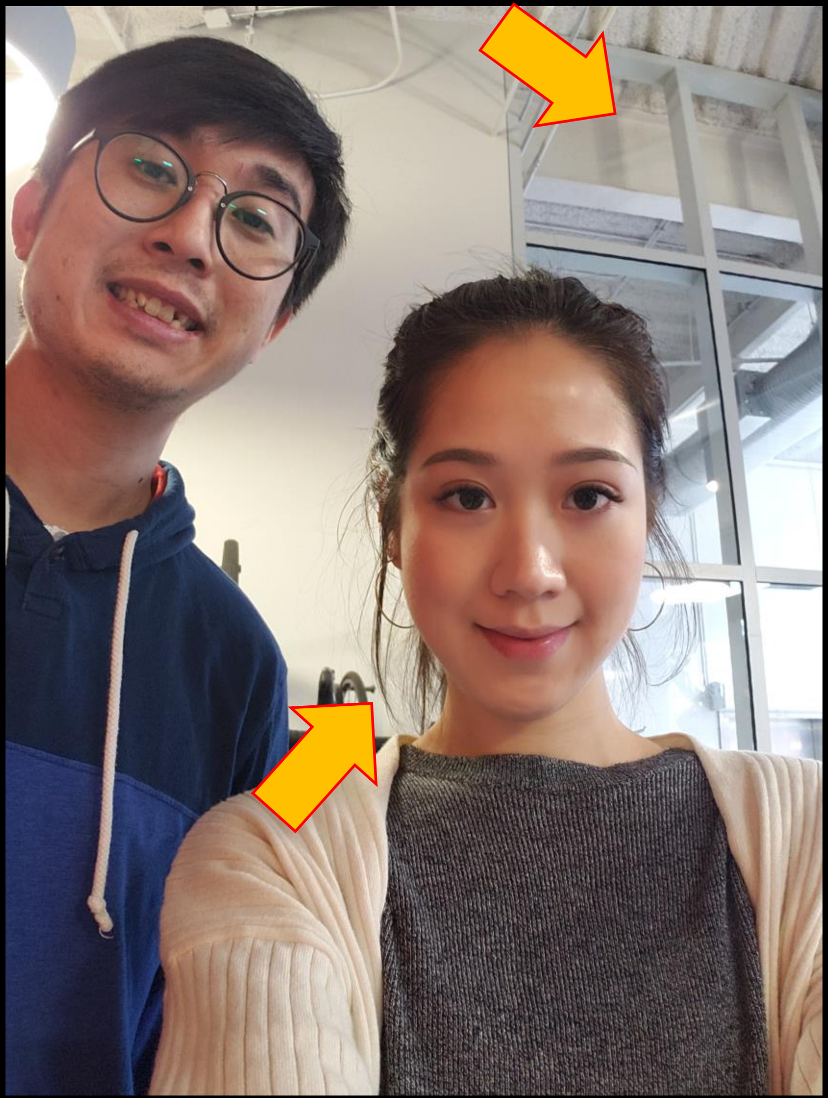
DxO Viewpoint3
Volume Deformation

Our method

Comparisons: Samsung S9+



Input (80° FOV)

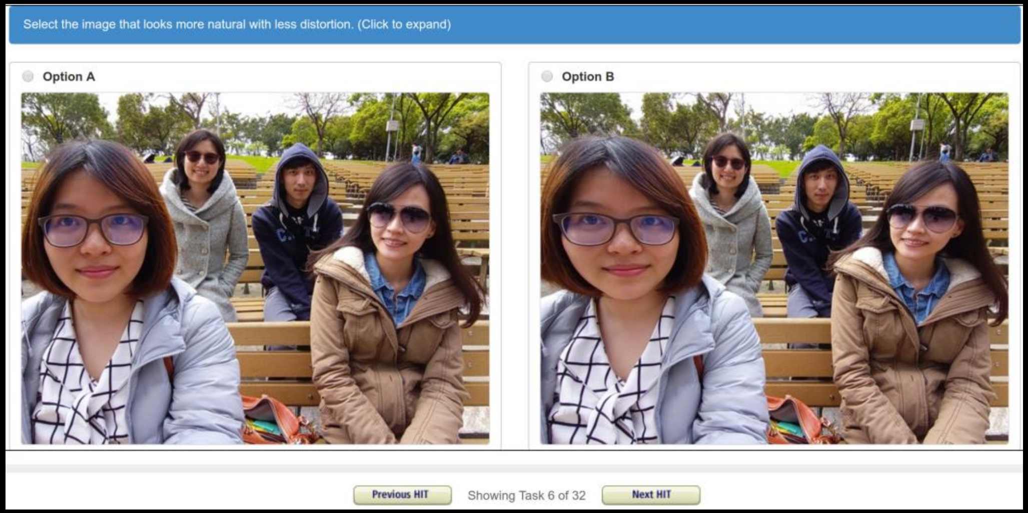


Samsung S9+
“Face Shape Correction”

Our method

User Study on Amazon Mechanic Turk

- 1047 photos from Flickr and collected by us.
- FOVs range from 70°-120°.
- 5 testers on each photo.
  - “looks more natural with less distortion.”



Comparator	Perspective projection	Stereographic projection	Mercator projection	Pannini projection
Favoring our method	92.4%	84%	81%	85%

Runtime

- Takes 920ms for a 12MP image on Qualcomm SDM845
  - Segmentation: 280ms (GPU)
  - Optimization: 340ms (CPU)
  - Warping: 115ms (GPU)

Limitation: missing face detection.

Input (104° FOV)

Output

Limitation: uncorrected body.

Input (90° FOV)

Output

Summary

- Introduce a distortion correction algorithm for wide-angle portraits.
- Based on mesh optimization and subject segmentation.
- Fully automatic and suited for mobile platform.
  - Basis for Wide-angle Group Selfie on Pixel 3.

Input (97° FOV)

Our method

Acknowledgement

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Thanks to Denis Zorin and all the photography models in this work for photo usage permission.

Thank you

- Find us in Poster session for **Live Demo** on Pixel 3!

  Wednesday, 31 July, 12:15-1:15 pm

Input (97° FOV)

Our method

Poster session for **Live Demo** on Pixel 3: Wed, 31 July, 12:15-1:15 pm

Input (perspective projection)
103° FOV

Our corrected result