Fast Burst Images Denoising

Supplementary Material

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Outline

Part I: Algorithm Validation

- *Homography Flow*
- *Consistent Pixels Selection*
- *Pixels Fusion*

Part II: Comparison with other methods

- *Teaser*
- *Static scene*
- *Portrait with small motion*
- *Complex scene motion I*
- *Complex scene motion II*

Part III: More Results

- *Handling motion blur*
- *Handling extreme low light*
- *Handling large occlusions*

Part IV: Failure Cases

- *Motion blurs on dynamic objects*
- *Clustered scenes*

Part I: Algorithm Validation

- Homography Flow
- Consistent Pixels Selection
- Pixels Fusion

Homography Flow

(Figure. 4)

Burst image (frame 0)

One sequence of captured clean burst images is shown here, then we added Gaussian noise with different std. to synthesize noisy burst images.

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Optical flow (Noise sigma = 20)

The motion estimation is performed on noisy burst images (sigma = 20) by different methods, and is transferred to register clean burst images.
Different fusion results of registered clean burst images are shown here.

Patch match (Noise sigma = 20)

Global homography (Noise sigma = 20)

Homography flow (Noise sigma = 20)

Optical flow (Noise sigma = 50)

The motion estimation is performed on noisy burst images (sigma = 50) by different methods, and is transferred to register clean burst images.
Different fusion results of registered clean burst images are shown here.

Patch match (Noise sigma = 50)

Global homography (Noise sigma = 50)

Homography flow (Noise sigma = 50)

Consistent Pixels Selection

(Figure. 5)

(for small motions)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

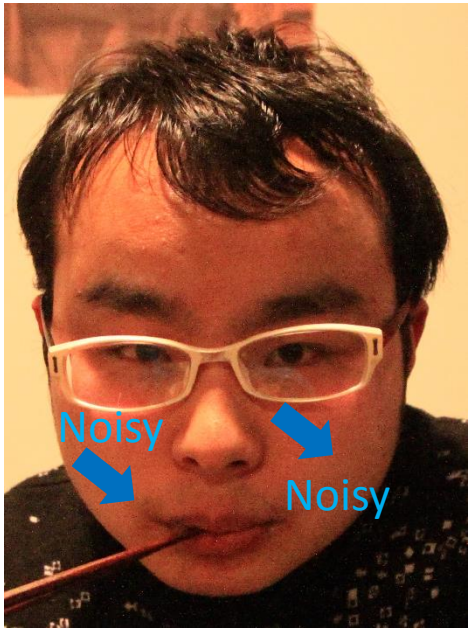
Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

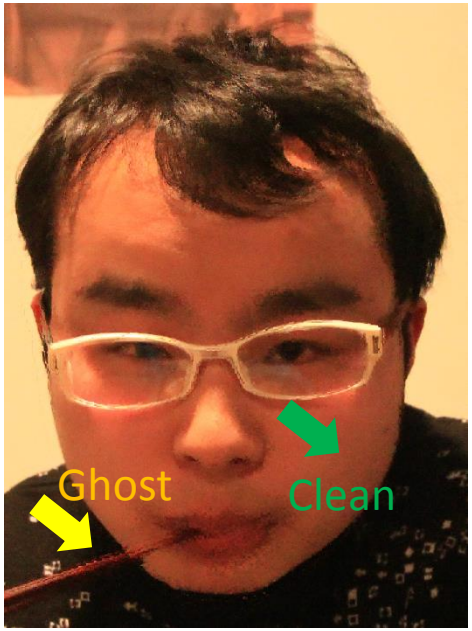
Burst image (frame 9)

Different consistent pixels selection strategies



Reference-based pixels selection:

- ✓ *Can maintain spatial coherence*
- ❑ *Can't collect enough samples*



Median-based pixels selection:

- ✓ *Can collect enough samples*
- ❑ *Can't maintain spatial coherence*

Temporal fusion by combining strategy:

- ✓ *Can maintain spatial coherence*
- ❑ *Can't collect enough samples for moving objects*

Temporal + multiscale fusion by combining strategy:

- ✓ *Can maintain spatial coherence*
- ✓ *Can collect enough samples for the whole image.*

Pixels Fusion

(Figure. 6)

PSNR on synthetic data (noise sigma = 30)

Global Align
+ Average
(26.81 dB)

Optical Flow
+ Median
(27.04 dB)

VBM3D
(29.82 dB)

BM4D
(29.49 dB)

Our Method
(Point)
(30.26 dB)

Our Method
(Patch)
(30.38 dB)

Part II: Comparison

- Spatial-temporal filtering

BENNETT, E. P., AND MCMILLAN, L. 2005. Video enhancement using per-pixel virtual exposures. Proc. ACM SIGGRAPH 24, 3, 845–852

- Optical flow + Median

LIU, C. 2009. Beyond Pixels: Exploring New Representations and Applications for Motion Analysis. PhD thesis, Massachusetts Institute of Technology.

- Lucky imaging

JOSHI, N., AND COHEN, M. F. 2010. Seeing mt. rainier: lucky imaging for multi-image denoising, sharpening, and haze removal. In Proc. ICCP.

- VBM3D

DABOV, K., FOI, A., AND EGIAZARIAN, K. 2007. Video denoising by sparse 3d transform-domain collaborative filtering. In Proc. European Signal Process. Conf., EUSIPCO.

- BM4D

MAGGIONI, M., KATKOVNIK, V., EGIAZARIAN, K., AND FOI, A. 2013. A nonlocal transform-domain filter for volumetric data denoising and reconstruction. IEEE Trans. on Image Processing, 1, 119–133.

Teaser

(Figure. 1)

(HTC 802d android phone)

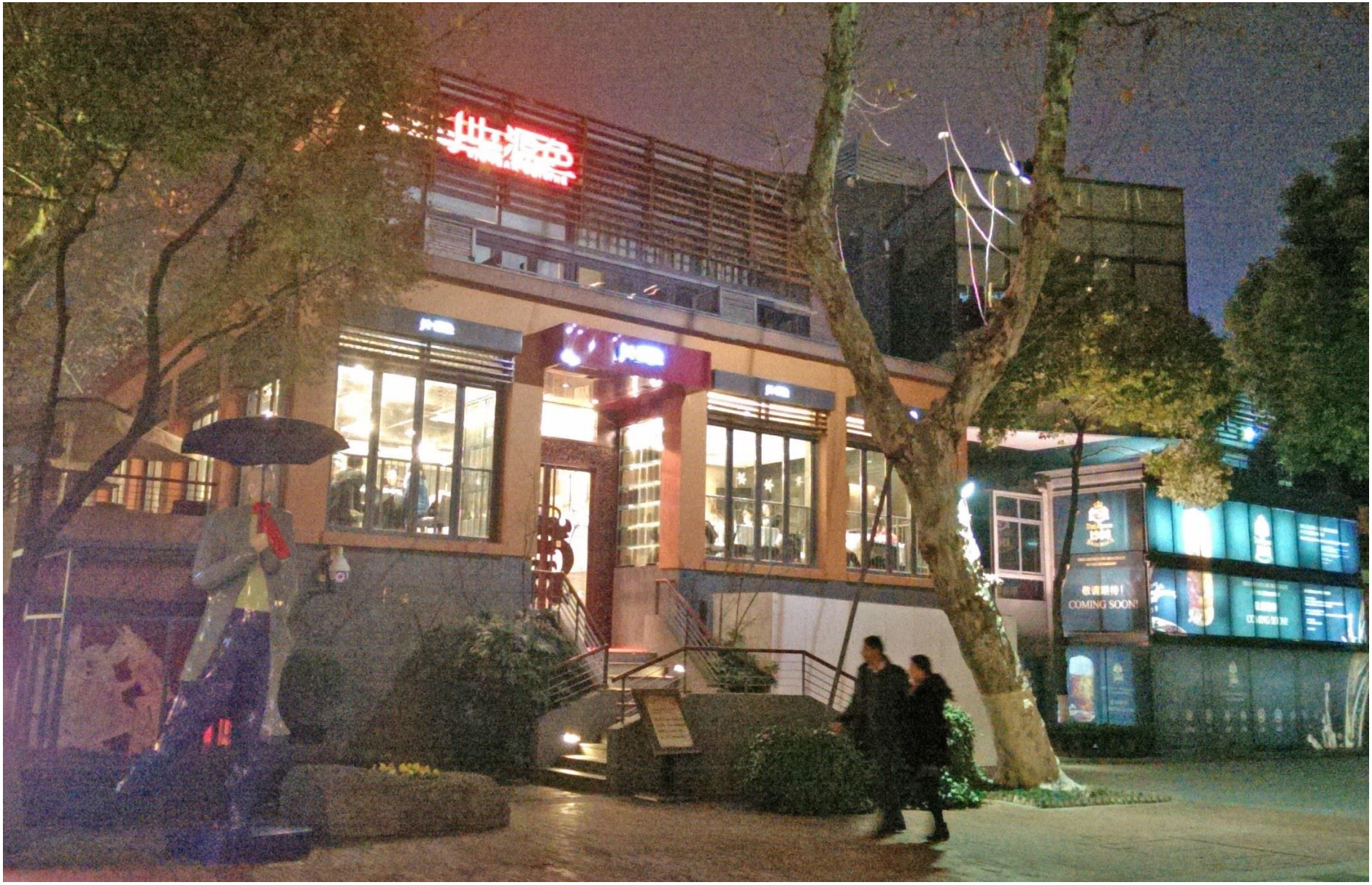
Burst image (frame 0)

Burst image (frame 1)

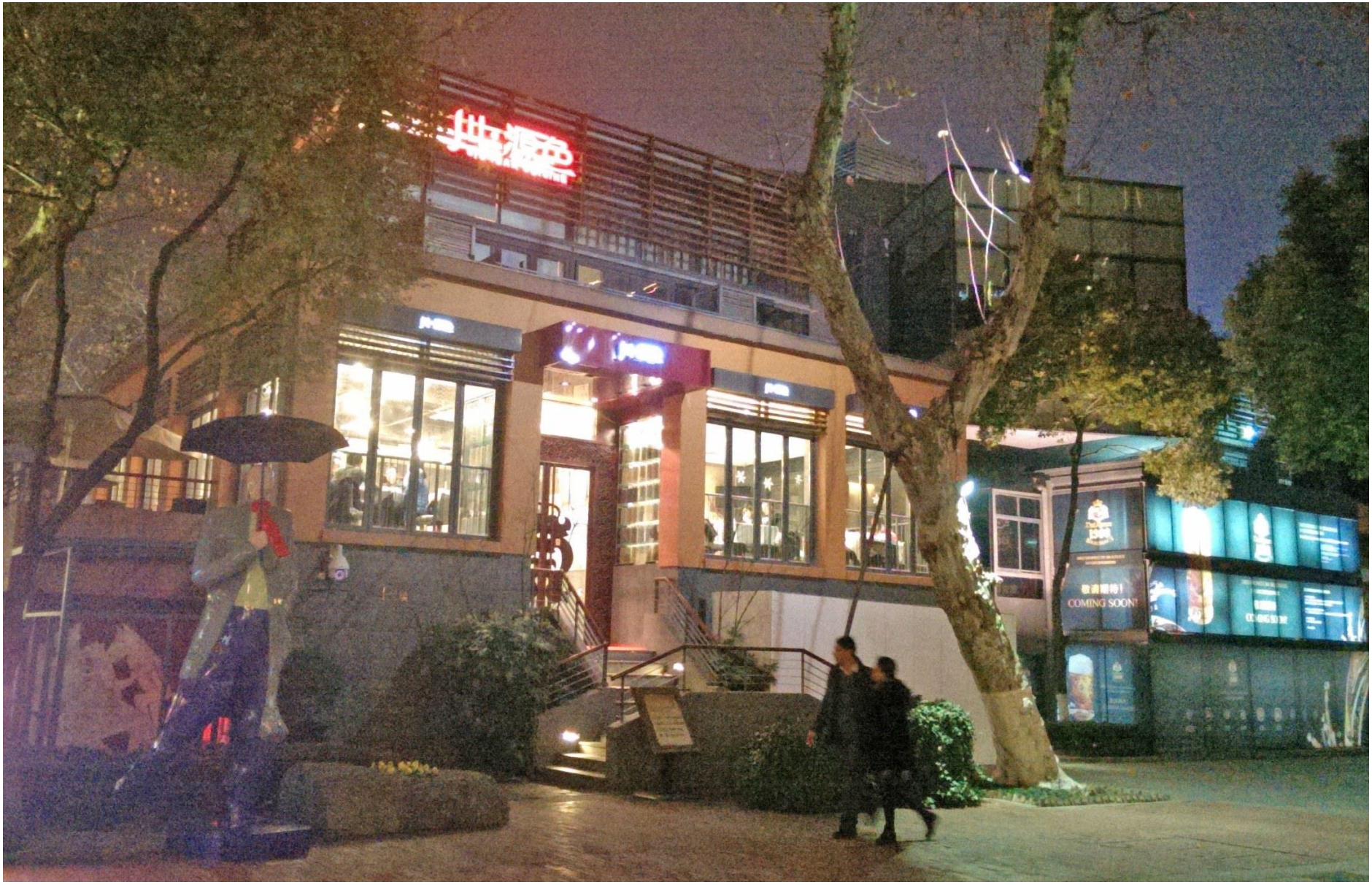
Burst image (frame 2)

Burst image (frame 3)

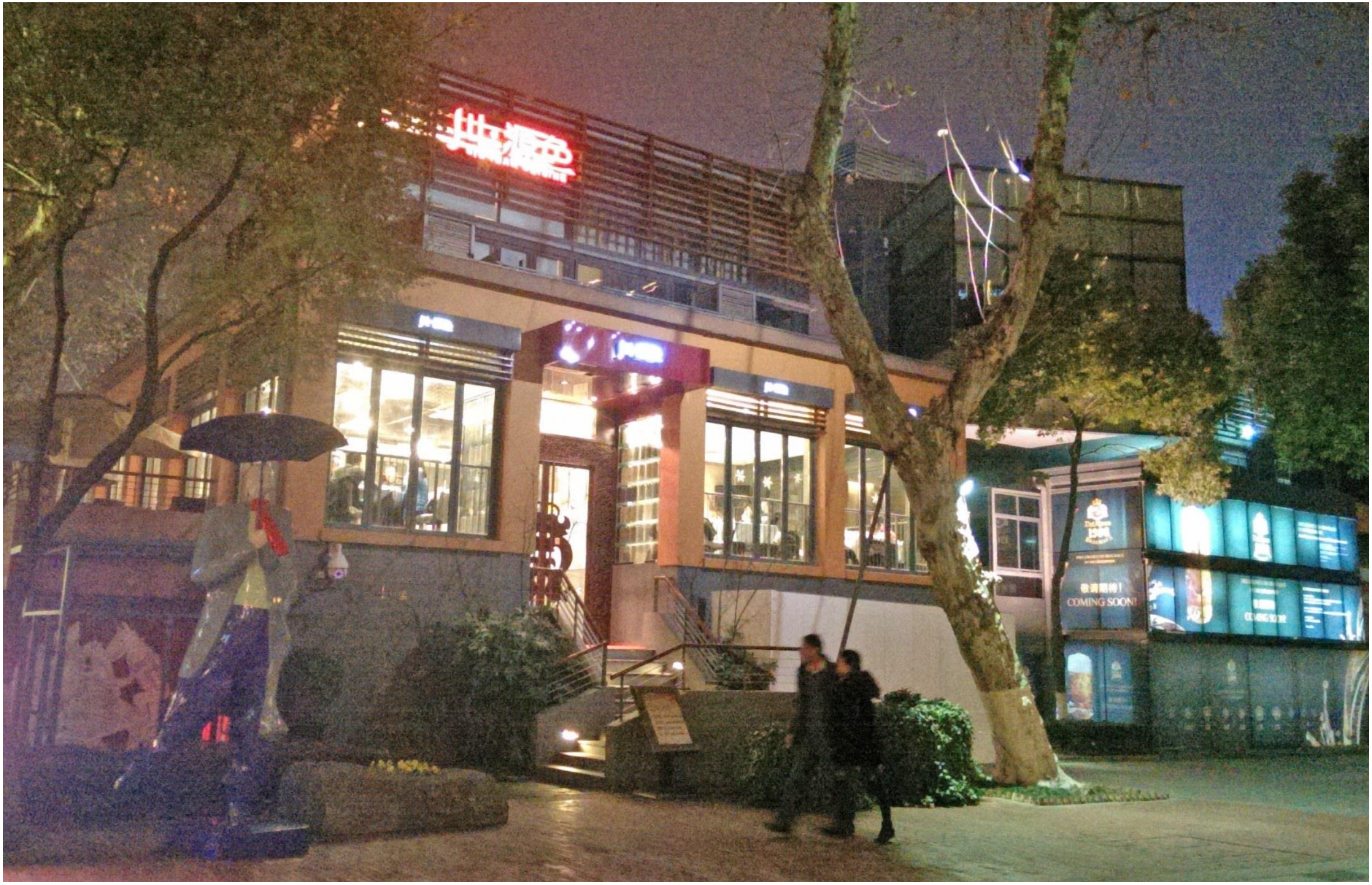
Burst image (frame 4)



Burst image (frame 5)



Burst image (frame 6)



Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result

Spatial-temporal filtering

Our result

Optical flow + Median

Our result

Lucky imaging

Our result

VBM3D

Our result

BM4D

Our result

Static Scene

(Figure. 8)

(HTC 802d android phone)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result

Spatial-temporal filtering

Our result

Optical flow + Median

Our result

Lucky imaging

Our result

VBM3D

Our result

BM4D

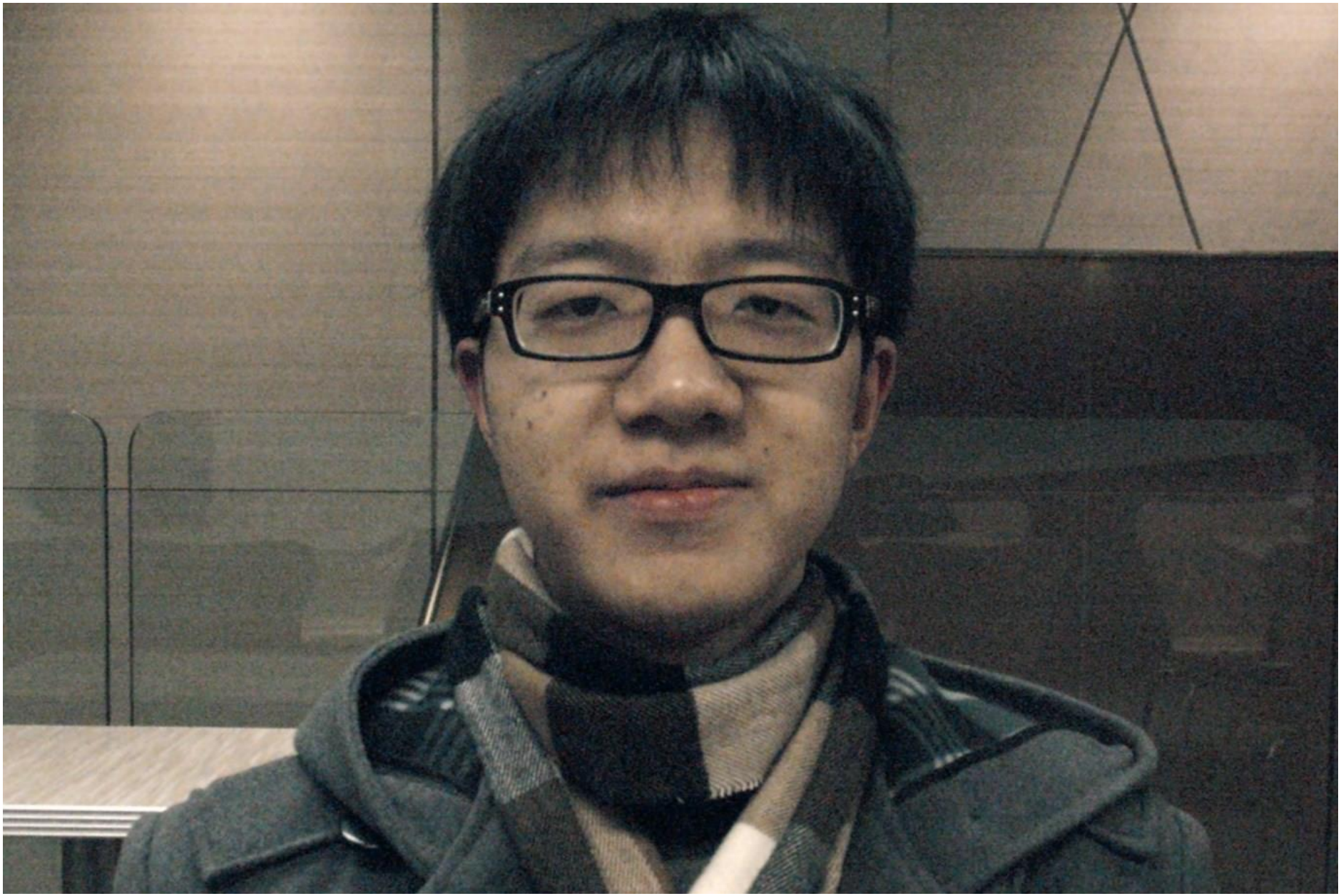
Our result

Portrait with small motion

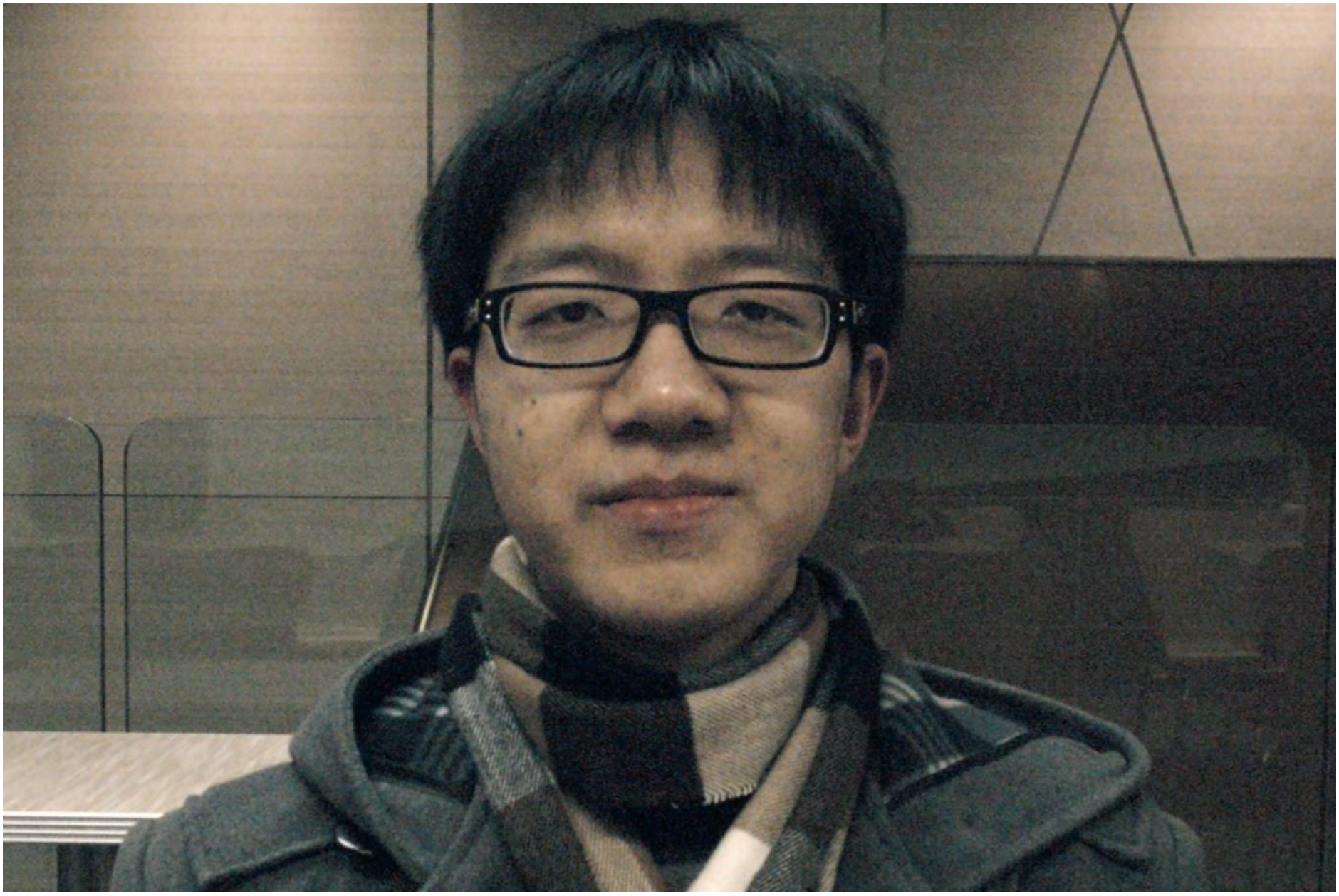
(Figure. 9)

(JVC GC-PX10 camera)

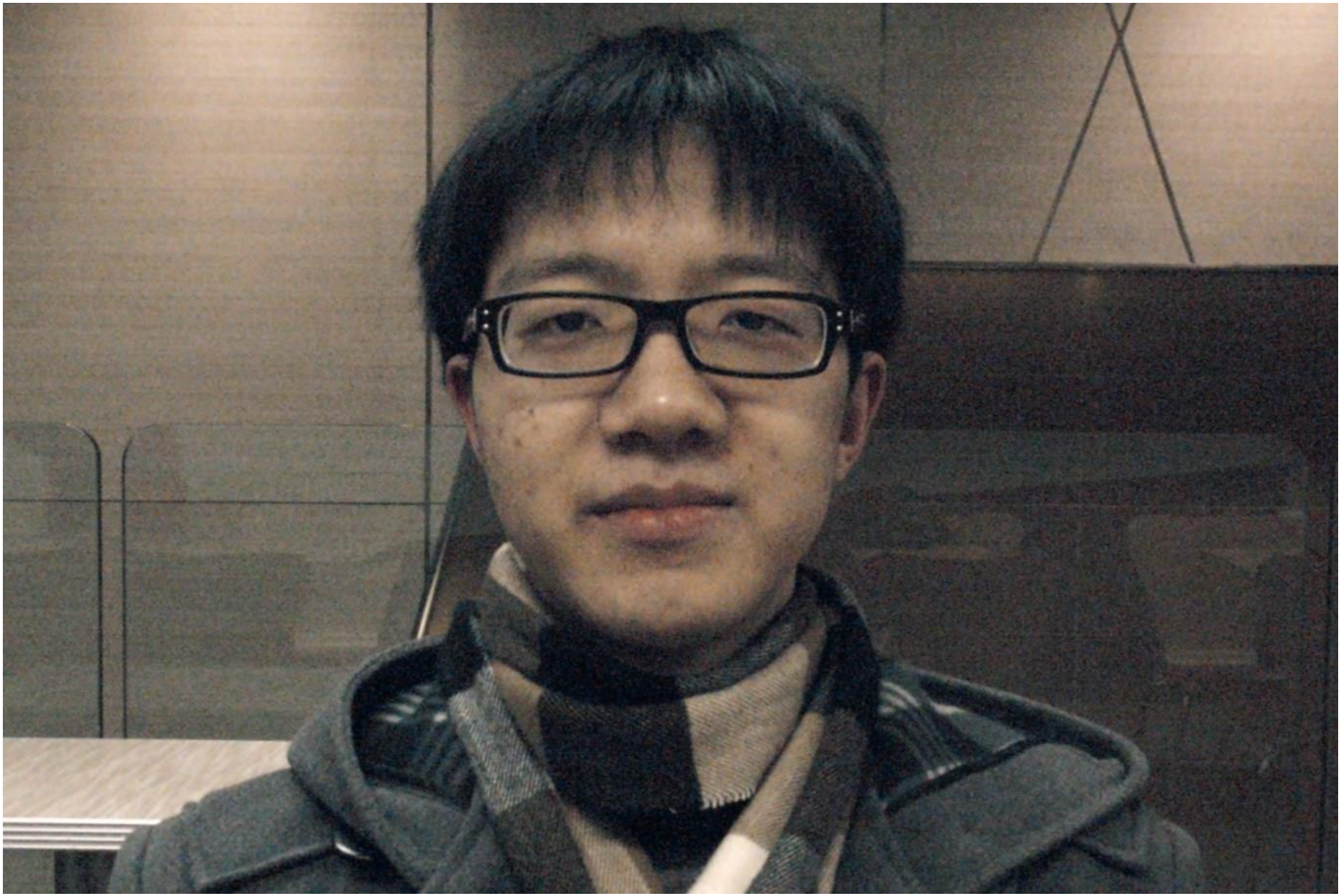
Burst image (frame 0)



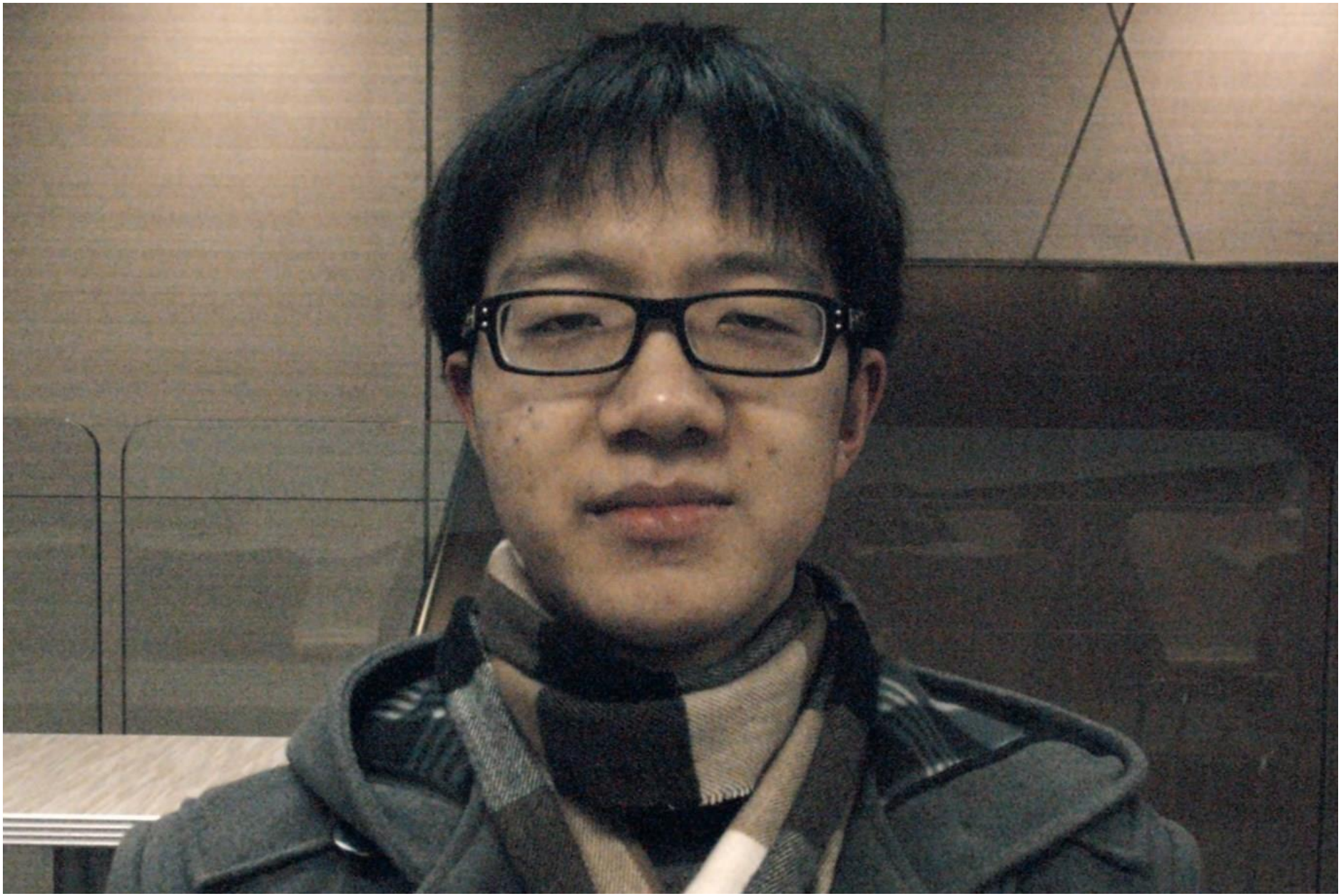
Burst image (frame 1)



Burst image (frame 2)

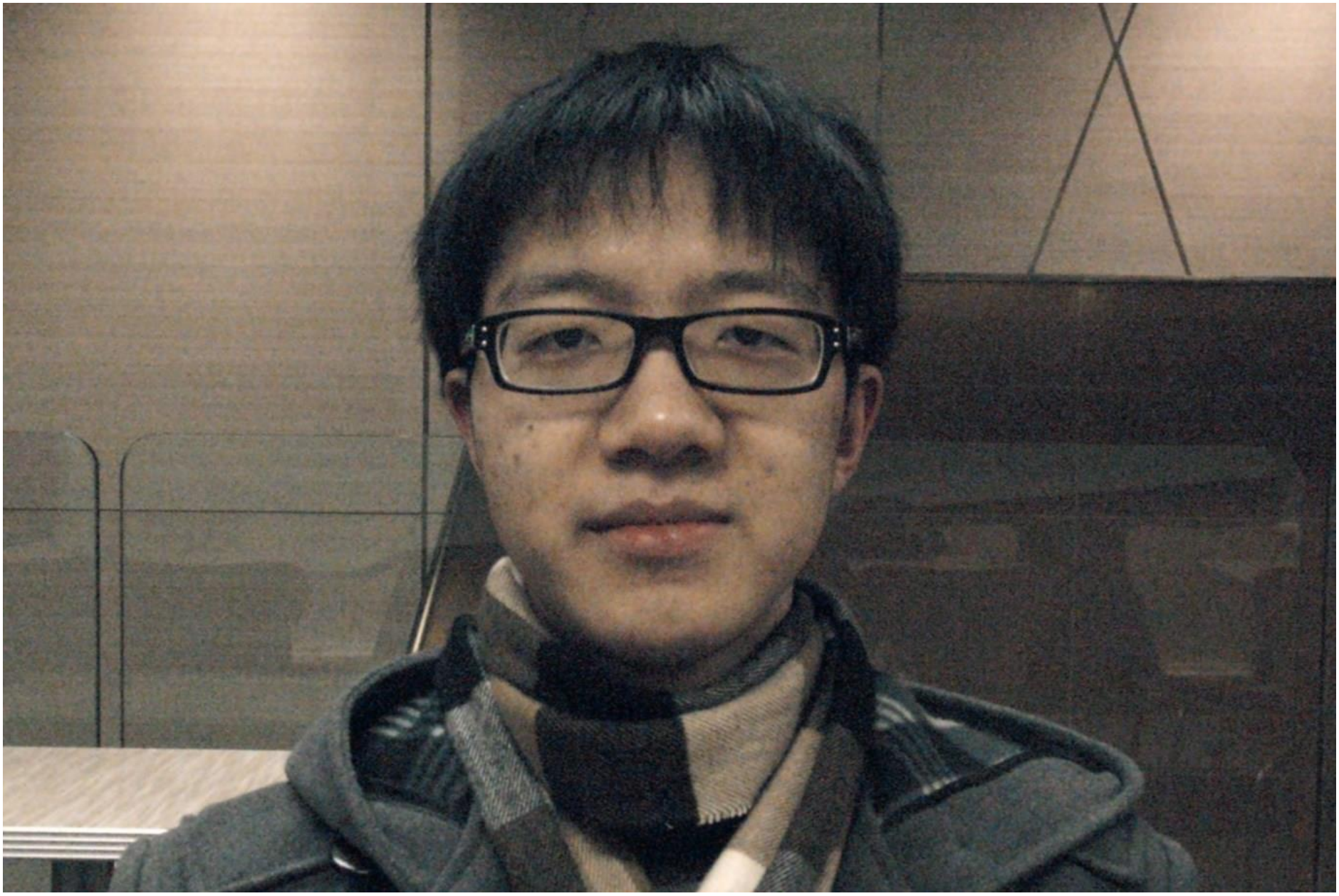


Burst image (frame 3)

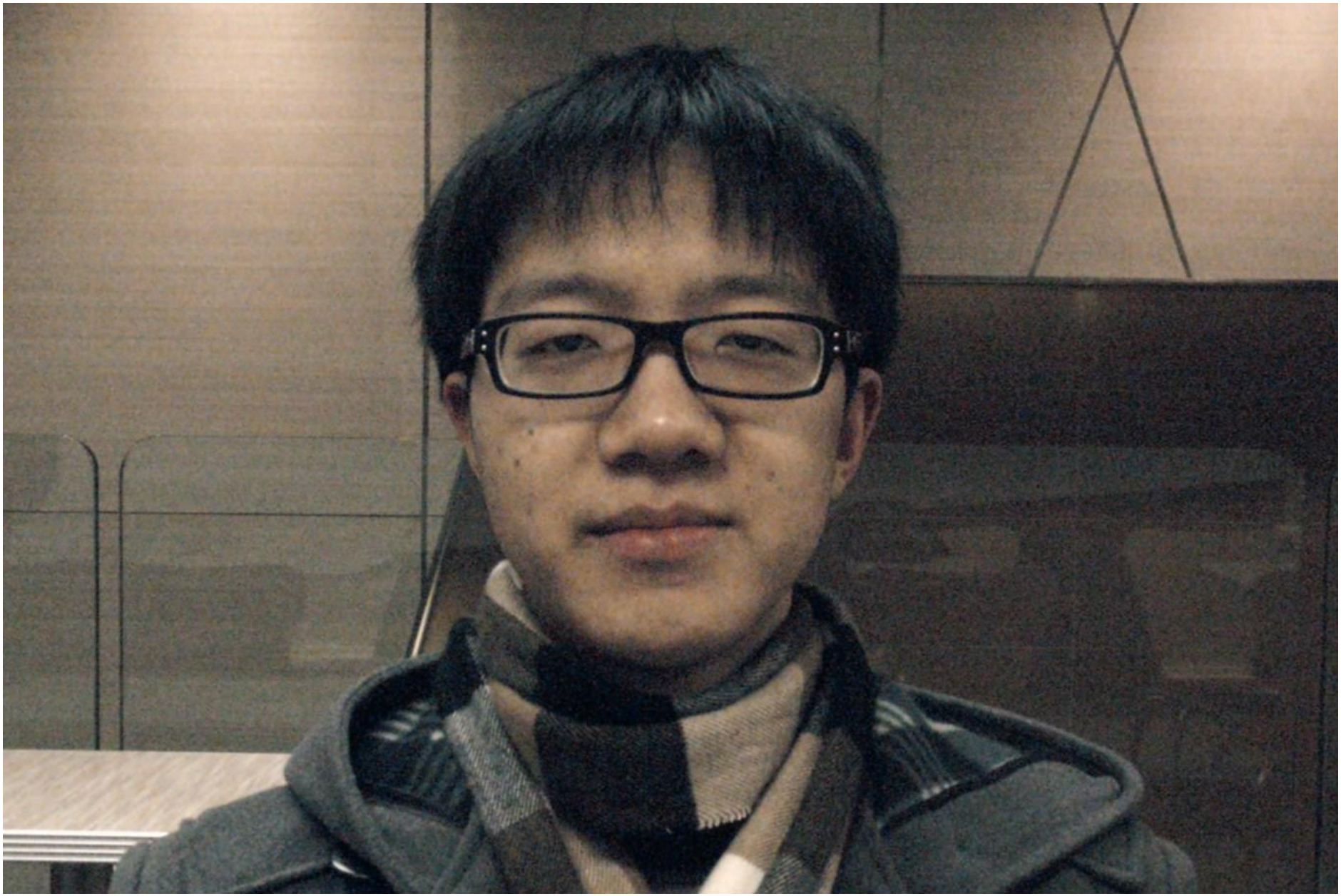


Burst image (frame 4)

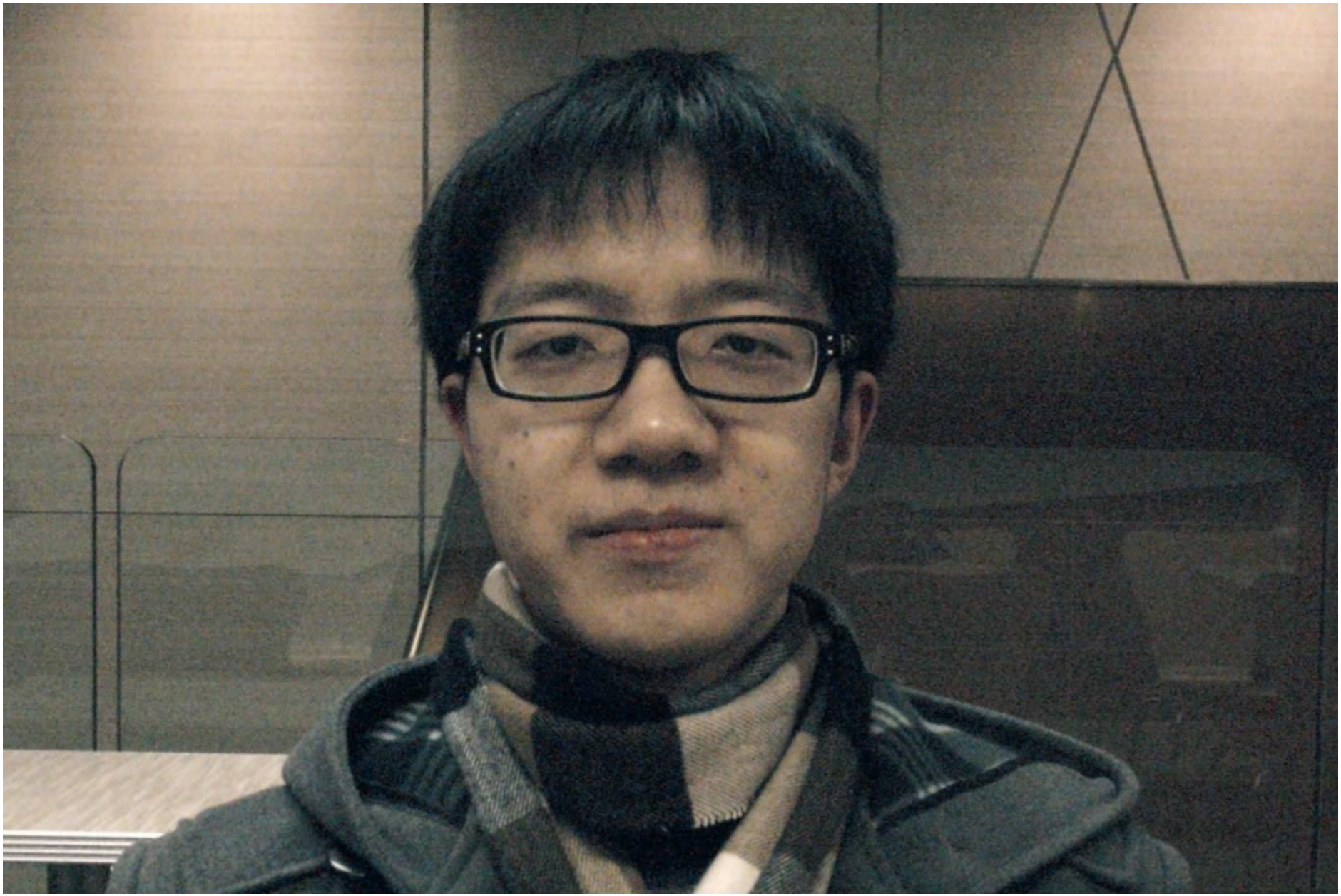
Burst image (frame 5)



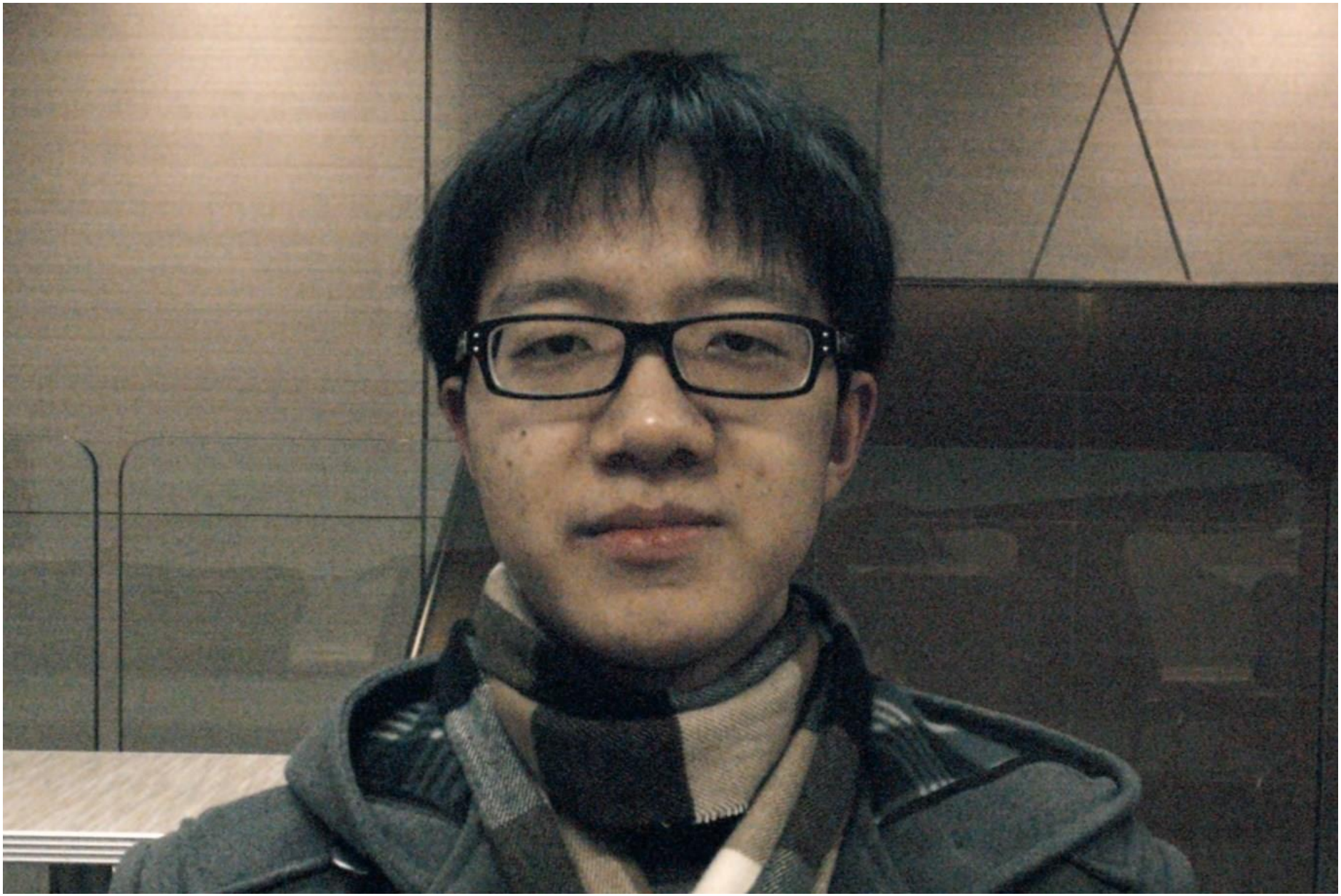
Burst image (frame 6)



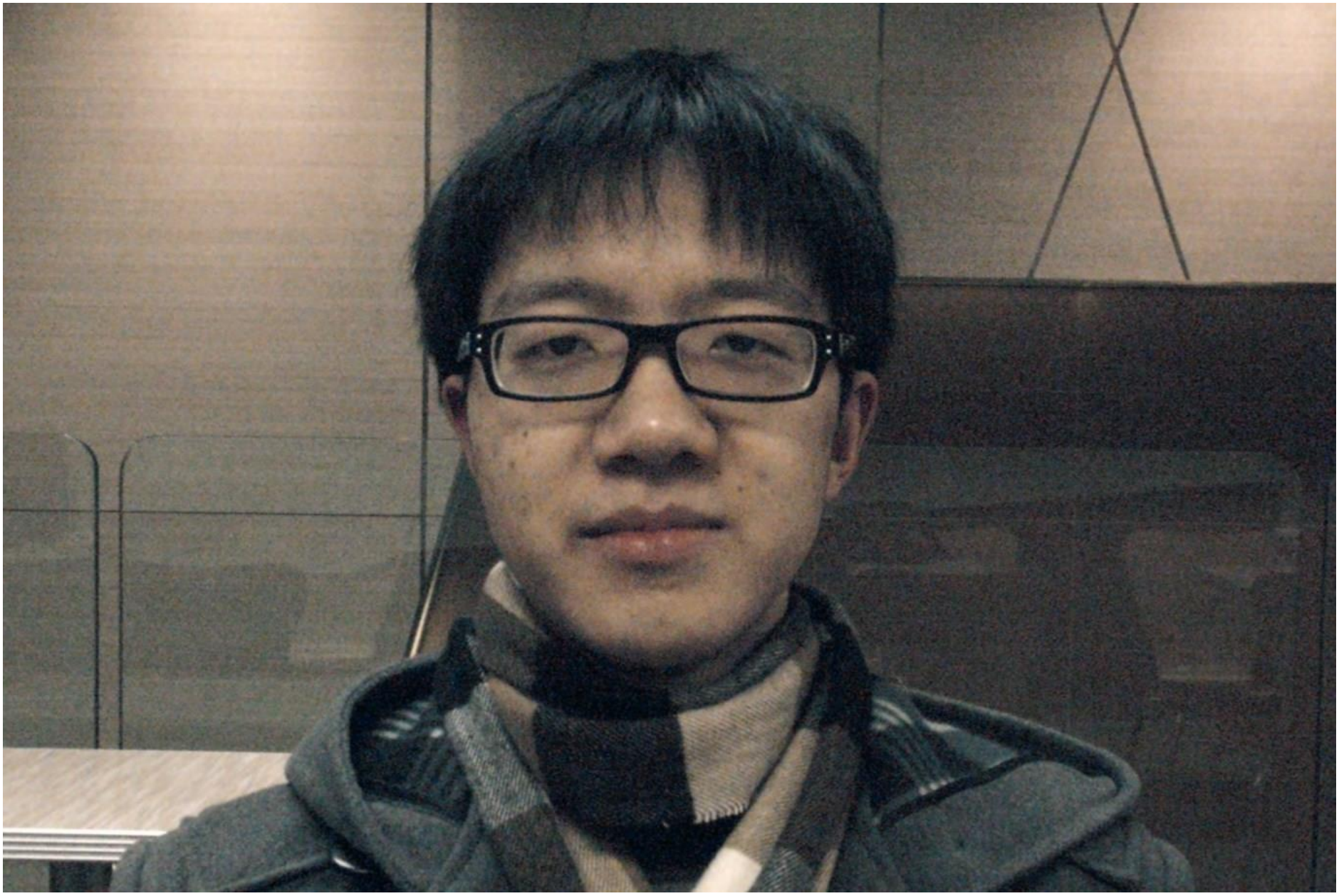
Burst image (frame 7)



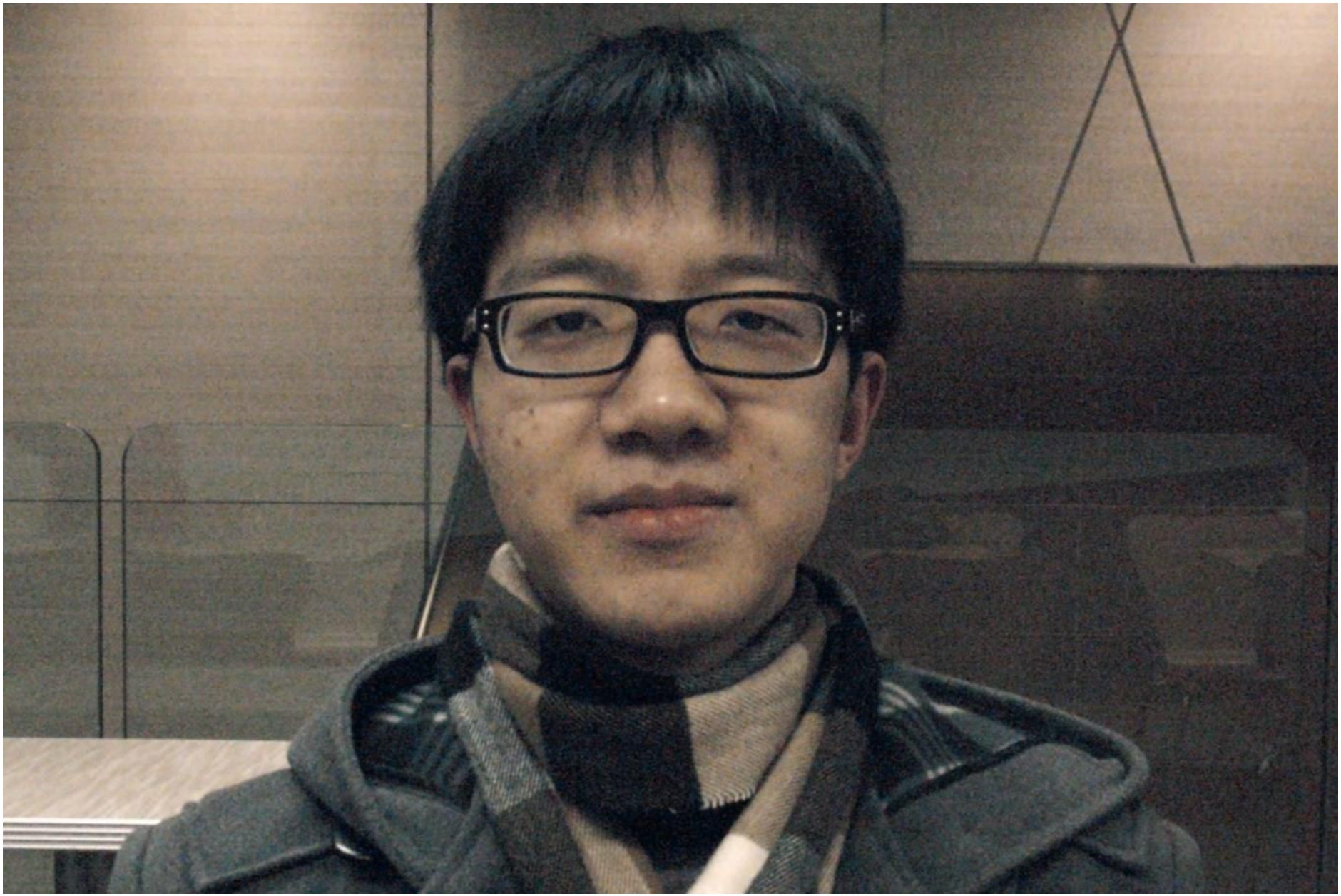
Burst image (frame 8)



Burst image (frame 9)

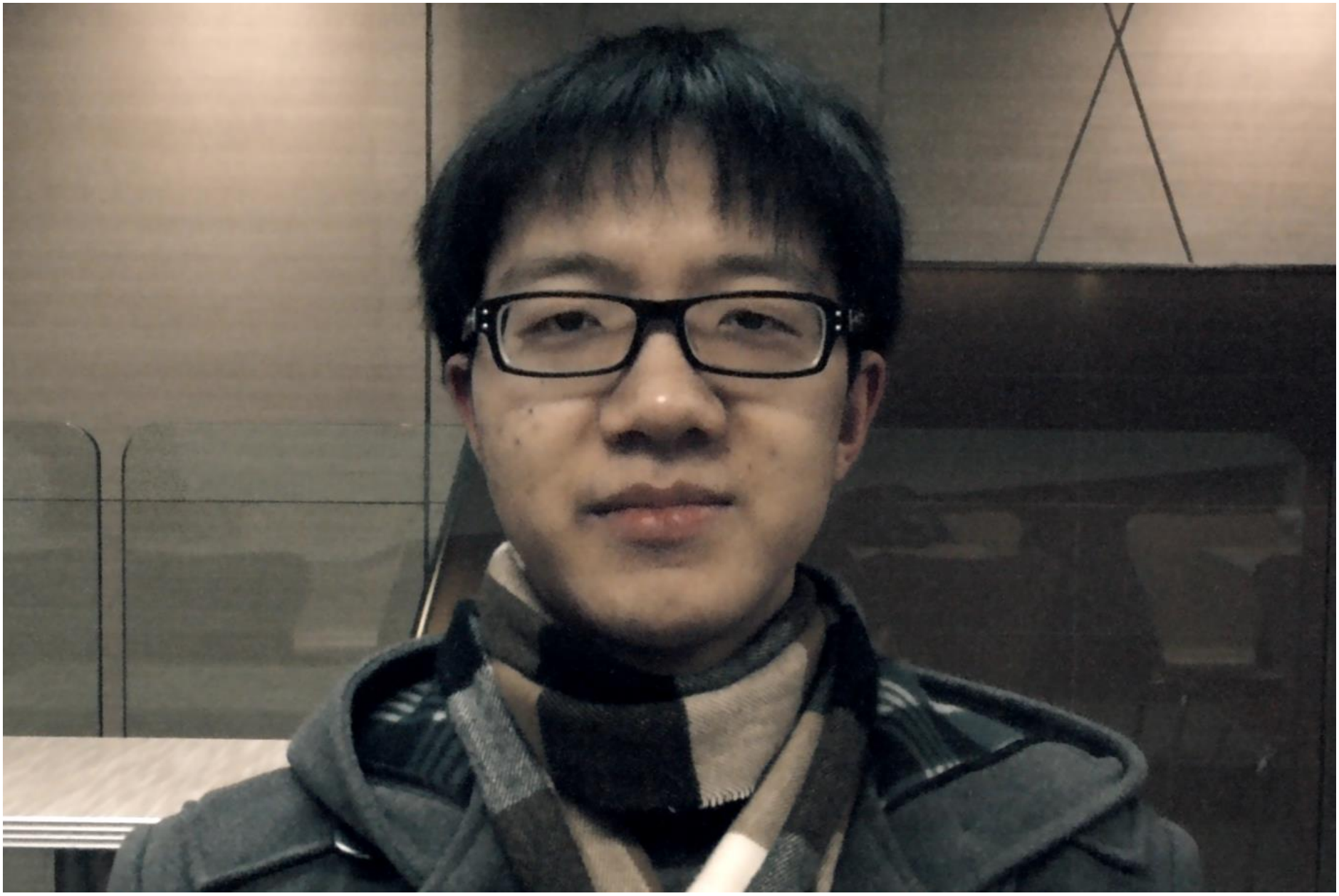


Reference image



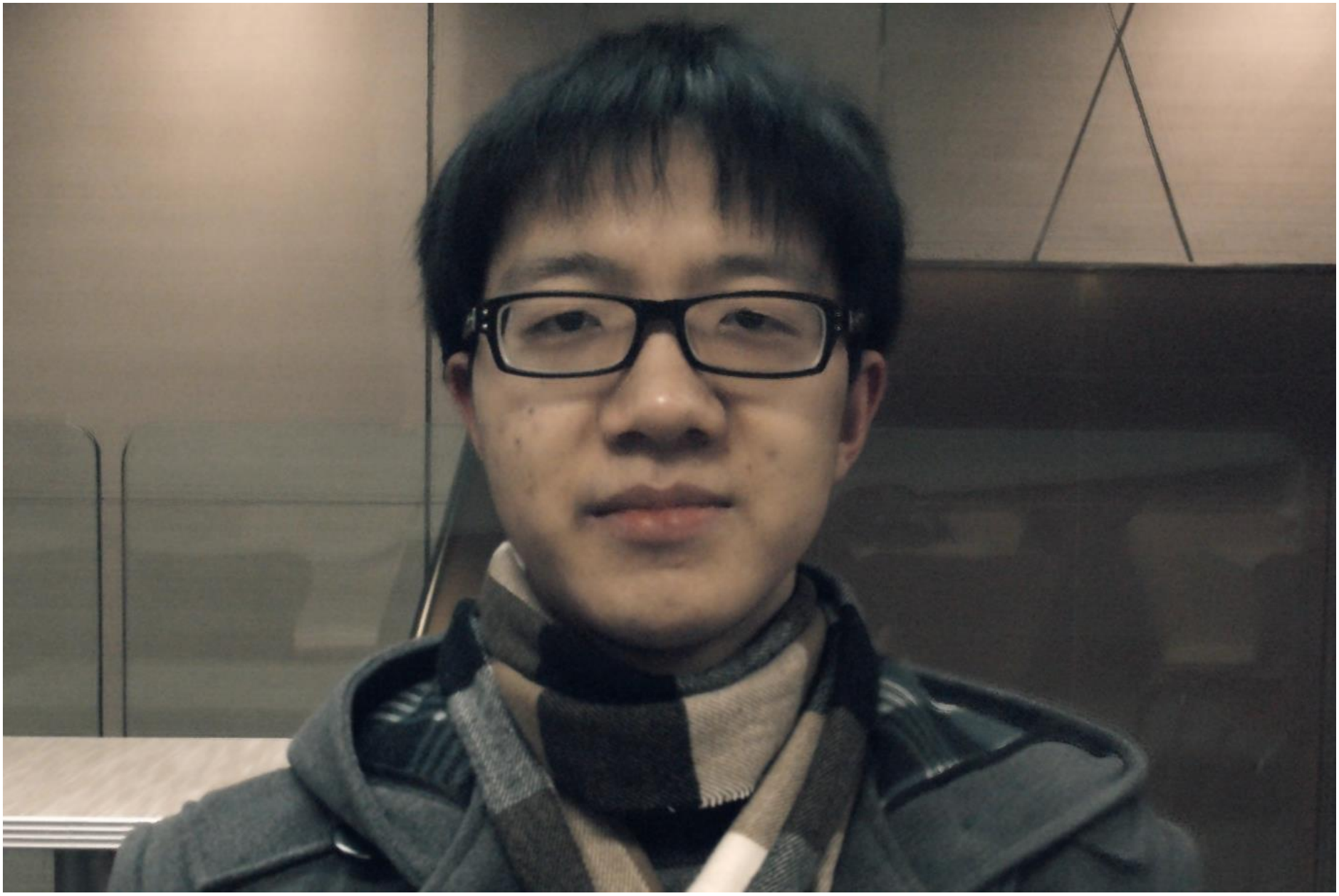
Our result

Spatial-temporal filtering



Our result

Optical flow + Median



Our result

Lucky imaging

Our result

VBM3D

Our result

BM4D

Our result

Complex scene motion I

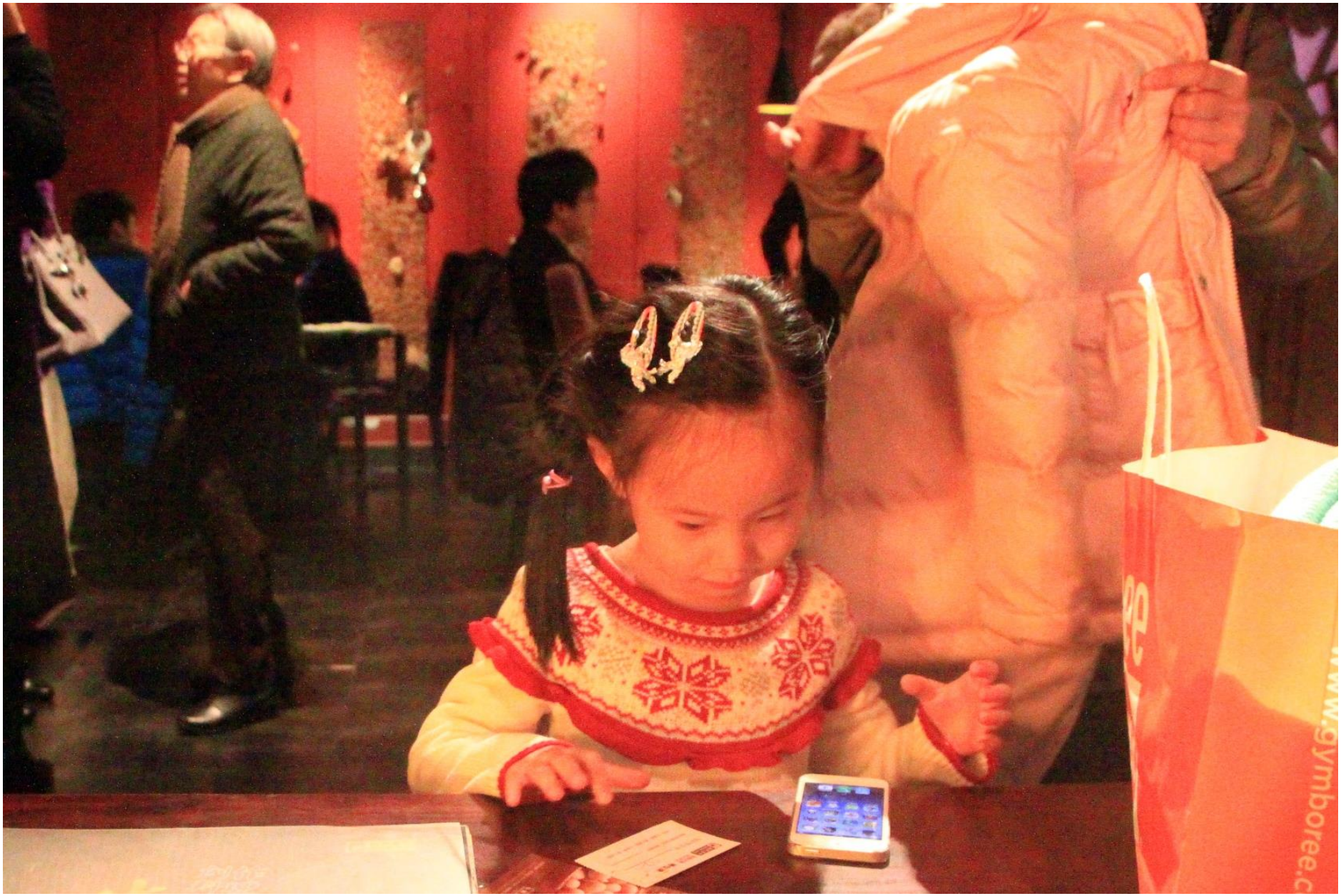
(Figure. 10)

(Canon EOS 500D camera)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)



Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result

Spatial-temporal filtering

Our result

Optical flow + Median

Our result

Lucky imaging

Our result

VBM3D

Our result

BM4D

Our result

Complex scene motion II

(Figure. 11)

(Nokia Lumia 920)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result

Spatial-temporal filtering

Our result

Optical flow + Median

Our result

Lucky imaging

Our result

VBM3D

Our result

BM4D

Our result

Part III: More results

- Handling motion blur
- Handling extreme low light
- Handling large occlusions

Handling motion blur

(Figure. 12)

(iPhone 5S cellphone)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image (frame 4)

Our result

Reference image (frame 5)

Our result

Handling extreme low light

(Figure. 13)

(iPhone 4S cellphone)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Reference image (brightness amplified)

Our result

Handling large occlusions

(Figure. 14)

(Canon EOS 500D camera)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result

Part IV: Failure cases

- Motion blurs on dynamic objects

- Clustered scenes

Motion blurs on dynamic objects

(Figure. 15 (a))

(Canon EOS 500D camera)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our Result

Clustered scenes

(Figure. 15 (b))

(Canon EOS 500D camera)

Burst image (frame 0)

Burst image (frame 1)

Burst image (frame 2)

Burst image (frame 3)

Burst image (frame 4)

Burst image (frame 5)

Burst image (frame 6)

Burst image (frame 7)

Burst image (frame 8)

Burst image (frame 9)

Reference image

Our result