

#### DoCam: Depth Sensing with an Optical Image Stabilization Supported RGB Camera

Hao Pan<sup>1</sup>, Feitong Tan<sup>2</sup>, Yi-Chao Chen<sup>1</sup>, Gaoang Huang<sup>1</sup>, Qingyang Li<sup>1</sup>, Wenhao Li<sup>1</sup>, Guangtao Xue<sup>1</sup>, Lili Qiu<sup>3</sup>, Xiaoyu Ji<sup>4</sup>

<sup>1</sup>Shanghai Jiao Tong University
 <sup>2</sup>Simon Fraser University
 <sup>3</sup> The University of Texas at Austin
 <sup>4</sup> Zhejiang University



#### > Depth Estimation on Mobile Devices

- > OIS Can Do More Than Image Stabilization
- DoCam: System Design
- > Performance Comparison with SOTA
- Conclusion

#### **Depth information is important!**



**3D Modeling** 



Augmented Reality



Relighting



Refocusing





Scene/object segmentation

#### **Depth estimation on mobile devices**



#### **Stereo Camera**

Depth "Z" and disparity "d" are inversly related:



#### **Structured Light Sensor**





Disadvantages:
1. Unstable
2. Need big baseline (>10cm)



Disadvantages:
Depth range is small (<1m)</li>
Application is limited



#### **Depth estimation on mobile devices**



Disadvantages:
1. Cost high and take up space
2. Cannot work well in outdoors scene





#### Depth from Multi-View Stereo (MVS) method





Moving camera with <u>50cm</u>

The key of the MVS is the accurate relative poses of moving cameras

- <sup>⊗</sup> Limitations:
- 1. Accurate depth map needs big motion
- 2. Cannot work with the fixed camera

#### Replace handheld motion with mechanically controlled motion









**Regular motion** 

Unregular motion

- > Depth Estimation in Mobile Devices
- > OIS Can Help with Depth Estimation
- > DoCam: System Design
- > Performance Comparison with SOTA
- Conclusion



### OIS prevents the video and image from being blurry





## **Optical Image Stabilization Techniques**



#### **MEMS sensors and acoustic injection**



**MEMS** accelerometer







#### **Demo Video: controlling lens motion with acoustic injection**



- > Depth Estimation in Mobile Devices
- > OIS Can Help with Depth Estimation
- DoCam: System Design
- > Performance Comparison with SOTA
- Conclusion

#### Relationship between gyroscope reading and lens motion (camera poses)









(c) Camera intrinsic paras



#### We can recover accurate camera poses with OIS model !



#### **Depth sensing with OIS-controlled lens motion**



(a) Multiple frames acquisition with OIS-controlled lens motion

(b) Depth estimation algorithm

- > Depth Estimation in Mobile Devices
- > OIS Can Help with Depth Estimation
- > DoCam: System Design
- Evaluation and Application
- > Conclusion

# Comparison with handheld small motion



**Reference frame (RGB)** 



Depth map from small handheld motion (10cm) Depth map from OIS-controlled lens motion (<3mm)

# Applications of depth sensing in mobile devices



**Face Authentication (liveness detection)** 

![](_page_18_Picture_3.jpeg)

**Refocusing (take pictures first, then focus)** 

![](_page_18_Picture_5.jpeg)

#### If OIS (lens) can be controlled, we can do more than stabilization

![](_page_19_Picture_1.jpeg)

Depth estimation by moving monocular camera

![](_page_19_Picture_3.jpeg)

Simulate equatorial instrument to track stars

![](_page_19_Figure_5.jpeg)

Super resolution (pixel shift)

![](_page_19_Picture_7.jpeg)

Light field camera

- > Depth Estimation in Mobile Devices
- > OIS Can Help with Depth Estimation
- > DoCam: System Design
- > Evaluation and Application

#### Conclusion

![](_page_20_Picture_6.jpeg)

#### Conclusion

We exploit the potential of the OIS techniques to facilitate depth estimation without handheld motion or on the fixed camera

- To the best of our knowledge, our proposed DoCam system is the first to use lens motion in the OIS module to achieve a robust depth estimation technology.
- We propose the formulation and mathematically model the conversion between camera poses and lens motions, and these constraints can be leveraged in recovering the camera poses.
- We develop a unified framework by which to estimate accurate camera poses with a micro-scale stereo baseline for use in high-quality depth estimation.
- We prototype the DoCam on Xiaomi 10 Ultra and demonstrate the accuracy of depth map output from our system.

![](_page_22_Picture_0.jpeg)

# Thanks watching!

# for