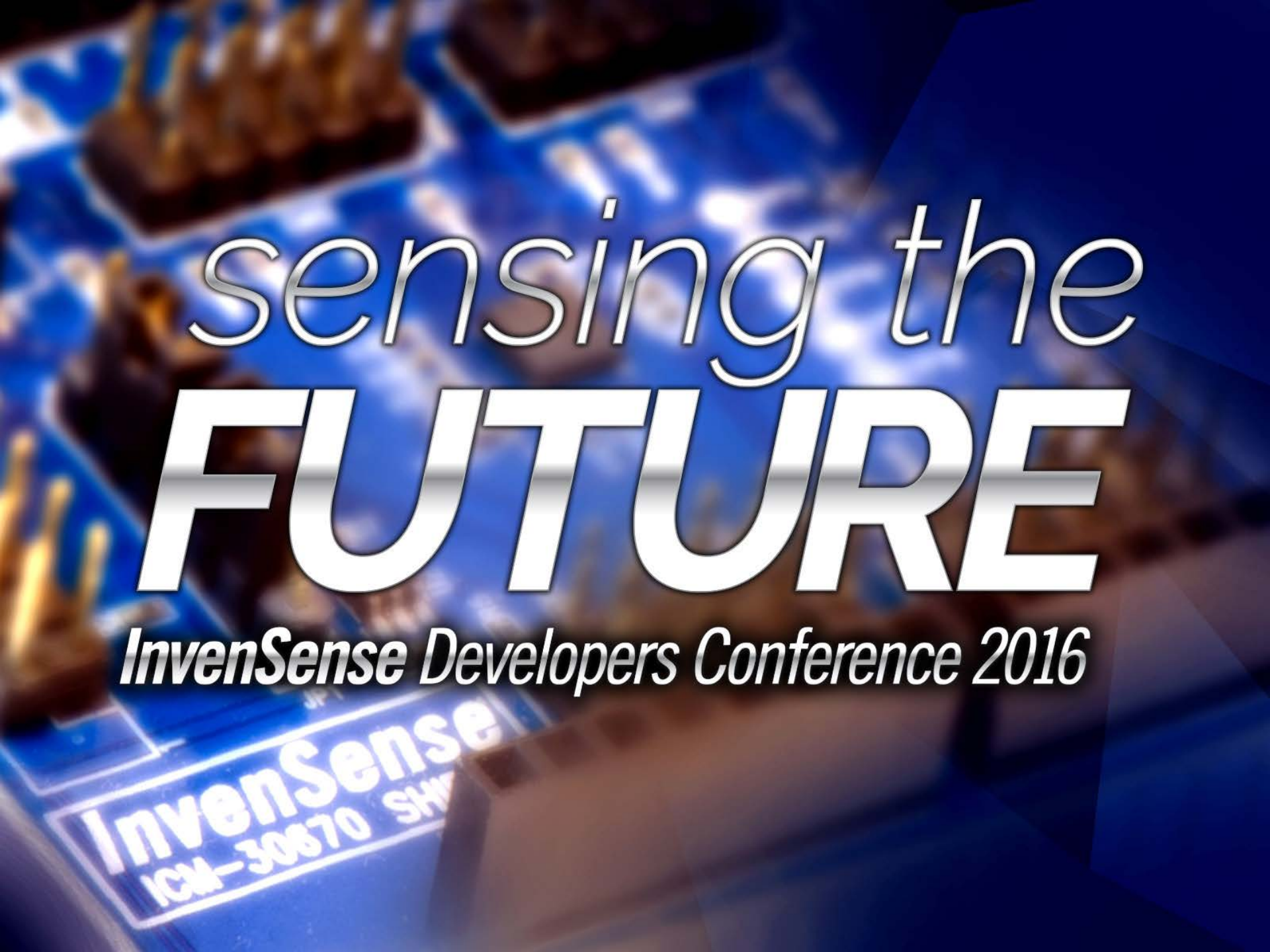

sensing the
FUTURE
InvenSense Developers Conference 2016
InvenSense
ICM-30670

Multi-Camera Applications

Mehran Ayat
Sr. Dir. Product Marketing and Amateur Photographer

To go beyond human vision

sensing the FUTURE

Human Vision facts *(sort of ☺)*

sensing the FUTURE

1. An angle of view of about 140° by 80°
   - Actual focal length of ~22mm with a view of ~90°
2. Perceive ~576 MP @120° angle of view
   - View extends to ~180 ° with higher equivalent resolution
   - Perception is via a combination of eyes and brain
3. Sensitivity equivalence of 800 ISO for adapted eye
   - Not a single shot frame, rather a video stream
   - It takes ~half hour for eyes to adapt to the dark
   - In day time sensitivity is 600X less at about 1 ISO!
4. Dynamic range of over 1 million to 1
   - A range of ~12.5 - 15 stops *(doubling or halving of light)*
   - *Seeing a faint star with moon in your eyes is 12.5 stops*

Sources: Clarkvision.com and Wikipedia

Multi-Camera Applications *(some!)*

sensing the FUTURE

Apple iPhone 7+

Huawei P9

Giroptic 360cam

Facebook Surround360

Light L16

Nikon KeyMission 360

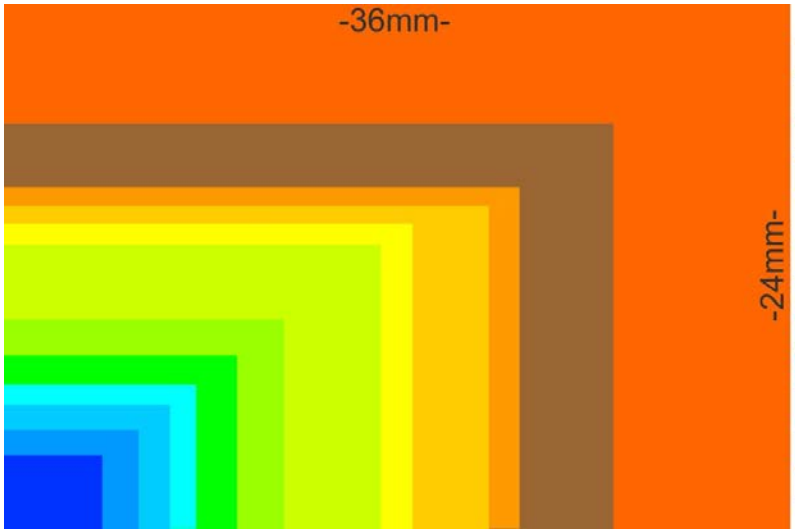
Why 2+ cameras instead of one?

sensing the FUTURE

1. Improve image quality where space is limited
   - Smartphones most critical dimension is height
2. More than one focal length and Optical zoom
   - Wide, Very wide, normal and telephoto options
3. Wrap around view (360°) for Sports, AR, VR
   - One camera cannot see behind its back ☺
4. Depth perception for Bokeh, AR and refocusing
   - Much easier to drive a depth map with 2+ cameras
5. The wholly grail! DSLR quality in your pocket
   - Cheap camera modules thanks to Smartphones
6. Combination of some or *all* of the above!

Image Sensor size, matters!

sensing the FUTURE



4.5 x 3.4 mm

Full frame DSLR image sensor is 56X the size of smartphones

A full frame sensor is equivalent to 35 mm film

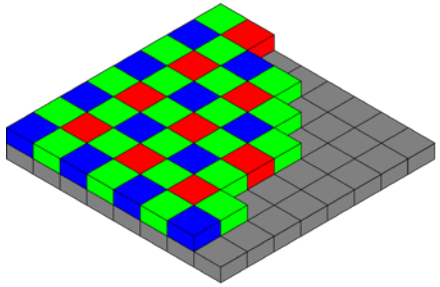
Dual-Camera for image Quality

sensing the FUTURE

- Dual-identical cameras
  - Same 12 MP image sensor
  - Same lens / focal length
  - One without RGB filter: Monochrome
  - No Optical Image Stabilization

Huawei P9

- Pro
  - Better low light with 2X+ light absorption
  - Allows depth perception and refocusing
- Con
  - Single camera with OIS gathers 4X to 8X the light absorption in a phone
  - Pixel level alignment of image sensors



RGB Filter

Dual-Camera: Wide, Tele, Zoom

sensing the FUTURE

- I7+: Normal and Tele camera
  - Optical zoom, up to 2X with no image quality penalty, same resolution
  - Normal camera has OIS with good low light image quality

iPhone 7+, Wide with OIS
Normal (tele), no OIS

- LG G5
  - Normal lens with OIS, good low light
  - Super wide view camera, no OIS
  - No zooming ability between cameras

LG G5: Wide 16MP w. OIS
Super Wide, 8MP, 135°, no OIS

Multi-Camera Virtual Reality

sensing the FUTURE

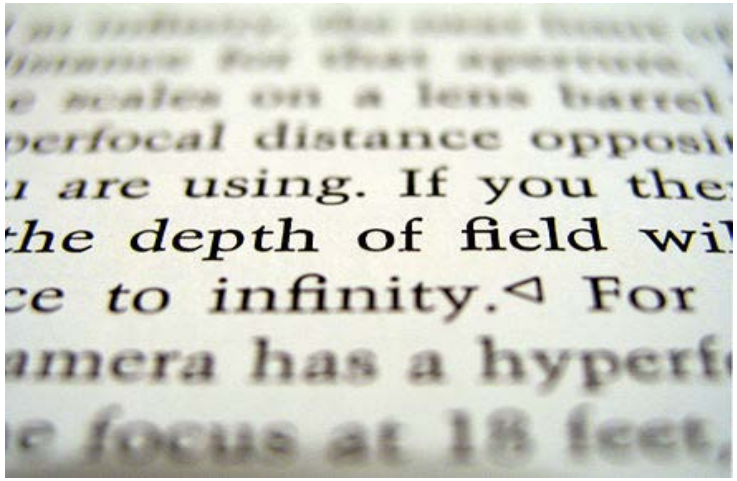
- Images from 3 x 185° view cameras
- 360° x 300° view with onboard stitching
- Six-axis sensor for image stabilization
- VR compatible with common viewers

Giroptic 360cam

Depth Map for Bokeh

sensing the FUTURE

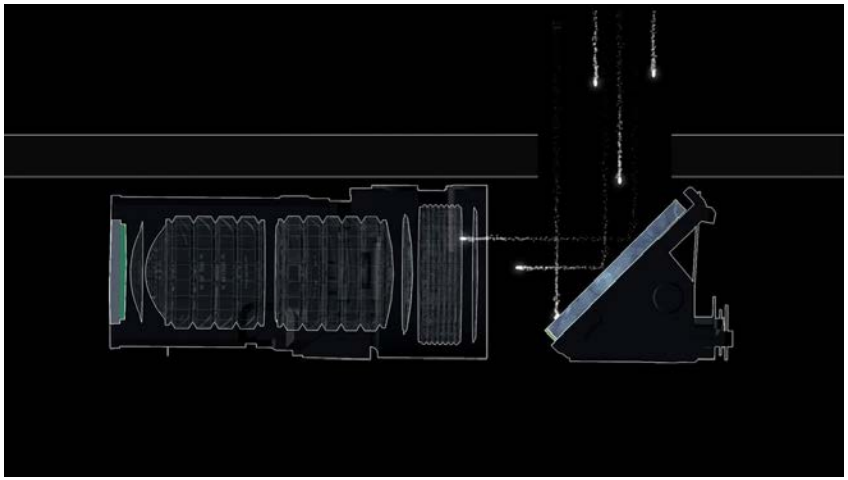
- i7+ Tele lens focal length of 52mm
  - ”Normal” perspective ~50mm Focal L.
  - A DSLR ”Portrait” lens is 75 to 135mm
- I7+ “Bokeh” with SW update
  - Bokeh is “the quality” of out of focus area of an image
  - DSLR tele lens w. aperture ≤ 2.8 achieves good bokeh
  - *A dual-camera lens can drive bokeh with depth map*



Computational Imaging: Light L16

sensing the FUTURE

- Digital computation instead of optical processing
  - E.g. Panorama, HDR & Light field (intensity + direction)
- Combine 16 cameras to achieve 35-150 mm FL
- Promises DSLR level image quality in your pocket
- Folded optics: Long focal length, in inch thick form
- Android based, heavy computational power



What does it all mean to me?

sensing the FUTURE

- Multi-cameras are way of the future in mobile space
- Ability to extract depth and direction of light as opposed to light intensity only with single camera
- Depth perception is a big challenge for AR
  - Ability to line up real objects with virtual objects
- API-reference with camera raw output to provide unique applications by developer community

Thank You