ESPROS Photonics Corporation

3D Facial Scanning

Industrial 3D Vision, Swissphotonics, HTW Chur, 21.06.18

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epc espros photonics corporation

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- The story around face ID
- Applications
- The challenge of the task
- 2D / 3D TOF face ID
- Look behind ESPROS face ID movie:
  an epc660 chip use case

  ---> The camera

  ---> Calibration and compensation

  ---> The benefit of image processing

Foundation and fab vision

Foundation

- established in 2006 by Beat De Coi
- privately held corporation
- 70 million CHF initial investment
- photonics chip design and manufacturing

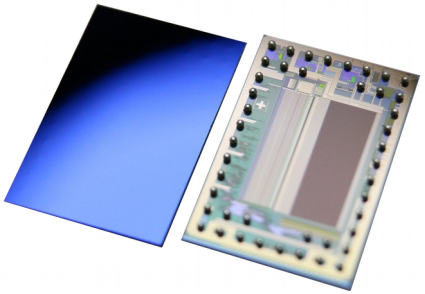
Locations

- Headquarters:
  - Sargans, Switzerland
- regional offices
  - Minneapolis, USA
  - Shanghai, China

Facilities

- 600m² class 1 cleanroom for backside processing
- 360m² class 100 cleanroom for testing and backend
- 80m² qualification facilities according JEDEC standards
- 60'000m² space built into solid rock for further expansion

ESPROS' offerings

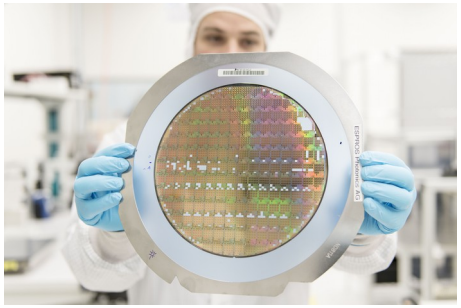


Imager Chips

TOF imagers
- 1 x 1
- 8 x 8
- 160 x 60
- 320 x 240

line imagers
- 1024 x 1

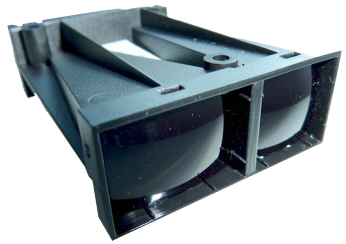
spectral sensing



ASIC and Foundry

- 150nm CMOS process
- 8” wafer size
- up to 6 metal layers
- 1 poly layer

- pixel design
- TCAD simulation
- IP building blocks
- floor planning
- tape out
- project management



Modules

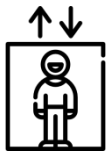
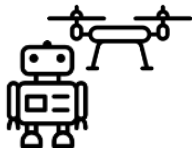
Evalkits / Cameras

SPEC 64 (SPM 64)
more to come…

TOF>range 611
TOF>frame 611
TOF>scan 611
TOF>cam 635
TOF>frame 660

Key Business Markets

ESPROS serves high-profile customers / partners across a broad range of end-markets and specific application needs

Key markets	Building Automation	Industrial	Mobile Robotics	Automotive	Consumer Electronics
					
Applications	• obstacle recognition • distance control • passenger approach • people counting • passenger monitoring • traffic control • people safety	• light curtain • gesture control • collision avoidance • object recognition • object dimensions • spectral sensing	• range finder • camera • SCANNING cameras • full sunlight (130kLux) • ground distance control • collision avoidance	• TOF ADAS solutions • full sunlight • mid range 30m (cwTOF) • long range >100m (pTOF) • night vision • vehicle interior monitoring • gesture control	• miniature spectral sensor • smart watch sensing • VR/AR TOF solutions • gesture control TOF
Selected active customers / partners	BIRCHER Reglomat, CEDES, iris, parksol, RTB, ID SENS	DELTA, OMRON, Leica Geosystems, HEXAGON, SICK Sensor Intelligence., Leuze electronic the sensor people, Baumer, DATALOGIC	TERABEE, Benewake, STARSHIP, marble°, HR HOALOHA ROBOTICS	TAKATA, Valeo, WAYMO, BOSCH, GENIUS PROS, LG	SAMSUNG, SAMSUNG ELECTRO-MECHANICS, HUAWEI, ·film, LG, ECOVACS ROBOTICS, VIAVI

ESPROS' products have successfully been deployed into several other markets like medical diagnosis, mass spectroscopy, science and research

SPECIALISED IMAGING, Gpixel INC. 长光辰芯光电, LG, ThermoFisher SCIENTIFIC

Yesterday – imagination? – a dream?

Was this a vision which the Grimm brothers tell us in the story of “Snow White”:

Source: cn.freeimages.com

«Mirror, mirror at the wall, who is the fairest one of all?»

- and now ?

Not at the time of the writing of the story nor some years ago like 1980s, somebody imagined how fast this proverb will become reality.

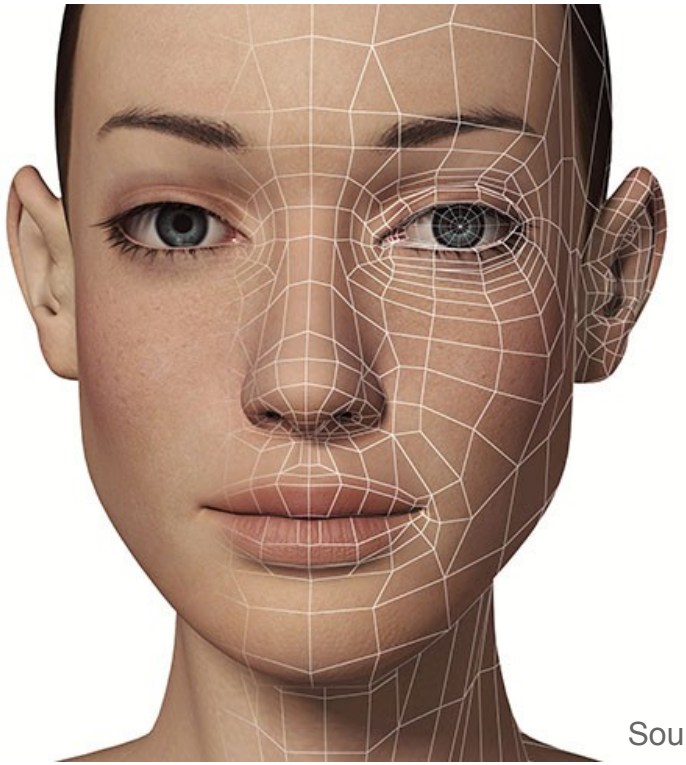
Today in 2018 - girls and boys are smiling into their mobile phones and thinking: «Mobile, mobile in my hand, unlock the screen to the fairest one of all».

Source: Mobilefox

Is it a miracle ?

which unlocks / gets access to their mobile

---> It is biometric authentication



Source: gettyimages

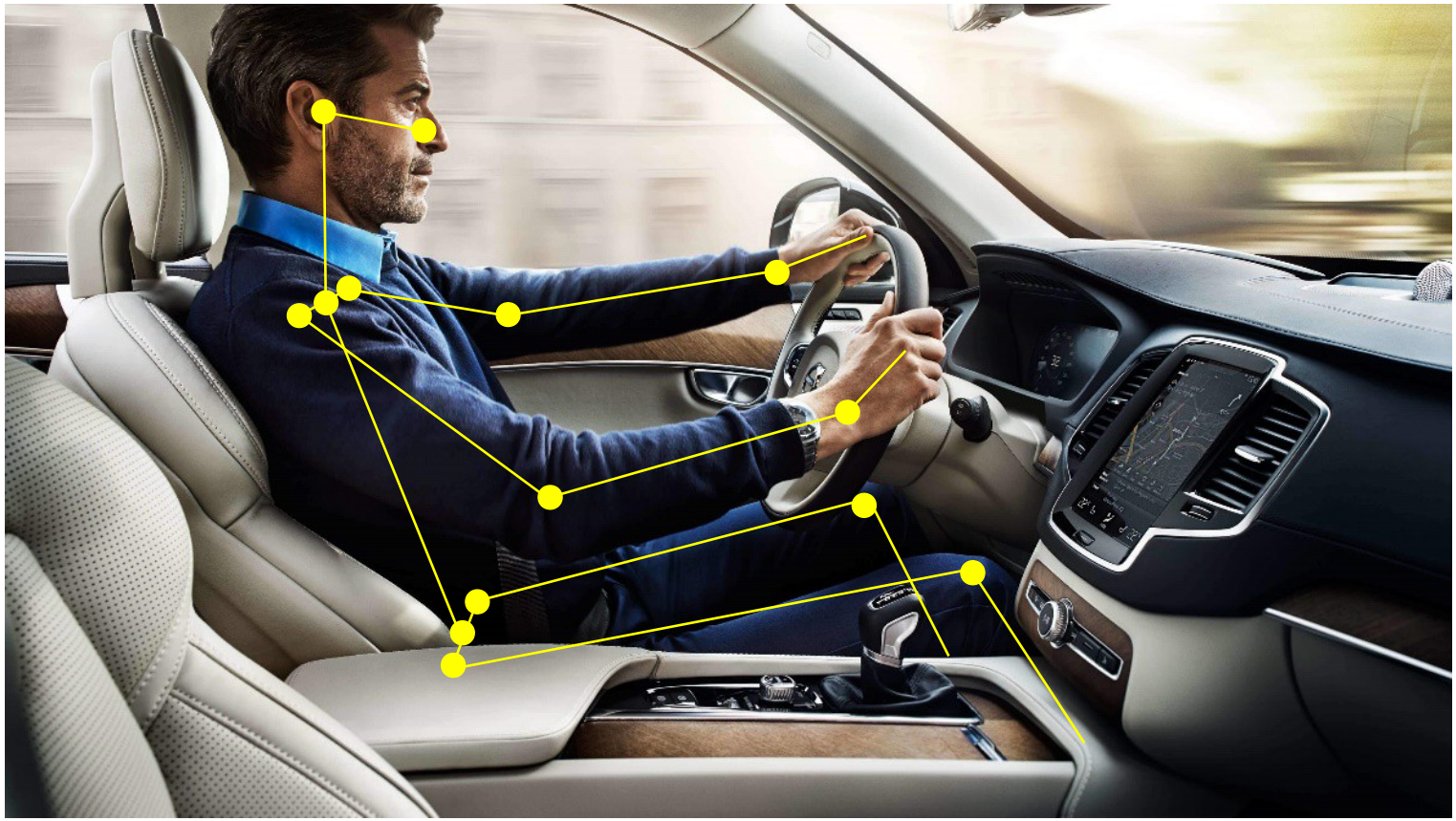
---> using Face ID (face identity document)

Applications

- Face ID
  - **Unlock** smartphone, tablets, computer screens
  - **IoT** (Internet of things): Home access, room access
  - **Car** access, driver access, driver's attentiveness, ...
  - **Security access** to hotel rooms, labs, cash machine, …
  - **Security control** on airport, train station, public building by passport, people identification terminal
  - **Police, forensic** for driver and identity check
- Same technology can be used for
  - Gesture recognition
  - Quality check for goods
  - Positioning systems to align to complex 3D bodies e.g. milking robots
  - and many more ...

Which task is to solve ?

---> Object abstraction ---> Data reduction & filtering

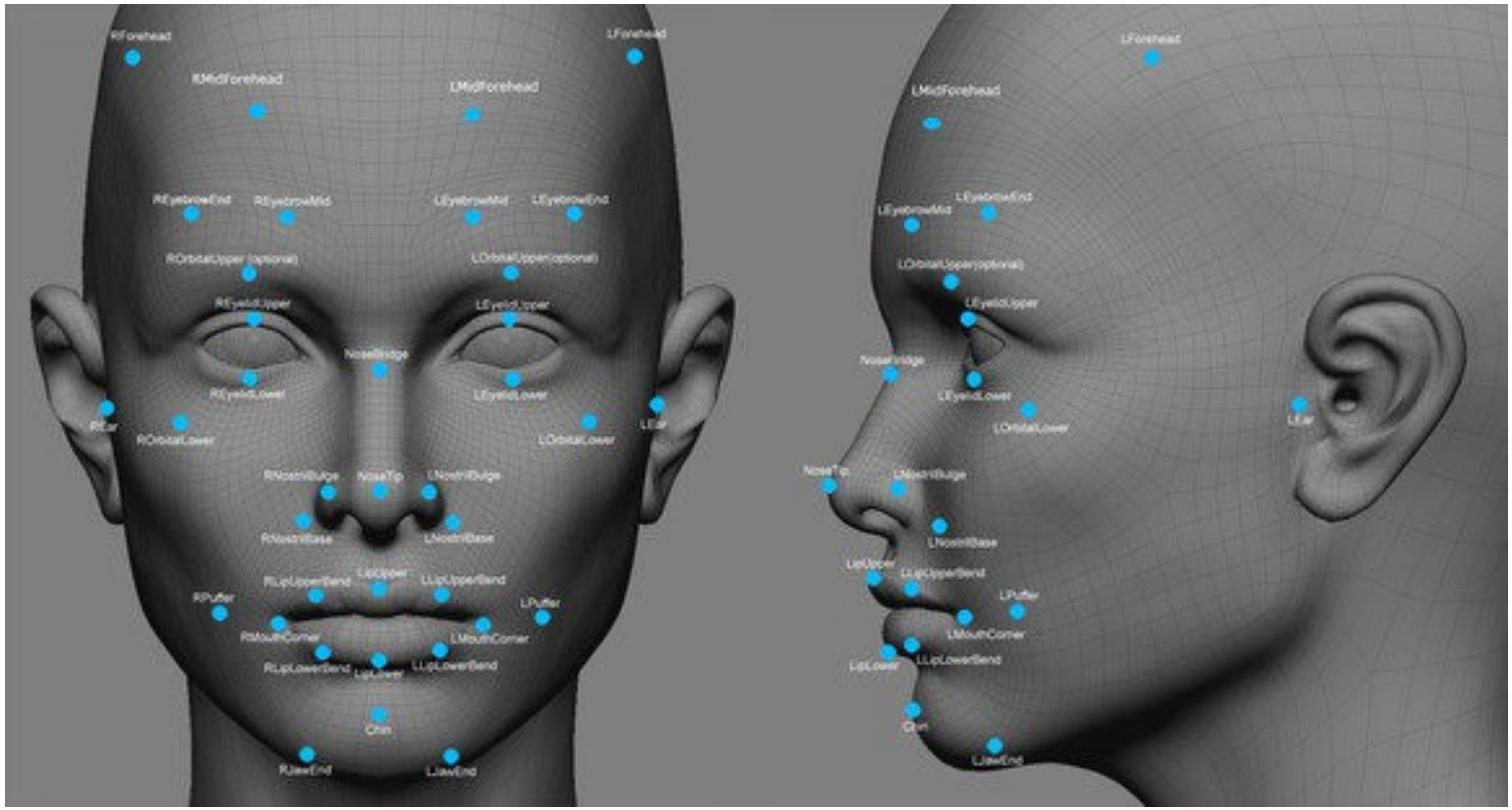


Source: Neonode

Which are real needs ?

---> Problem description

---> Object abstraction ---> Data reduction & filtering



Source: Worldpress

2D based face ID: Weaknesses

Data generation

- Based on 2D images black & white or color
- 3D data are based upon / extracted from 2D image data by different views (turning of head) or stereo cams

Weakness for the security systems

- They cannot distinguish between real or artificial word
- Data can be faked, even so-called living data e.g. by presenting videos on screens

3D TOF face ID: Strengths & benefits

- Received image data needs synchronization with the illumination
- Data needs to match dynamic range of the illumination
- Needs true 3D model reflecting the modulated light
- Run-time check by security algorithm if 3D model is living person of static mask
- Additional security features on the fly during run-time
  - Change of illumination modulation frequency
  - Change of illumination angle, intensity and sources

Conclusion: Such a **living dataset** cannot easily be faked

ESPROS facial ID movie

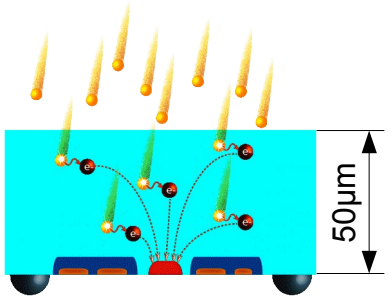
Demonstration camera

- DME 660 camera with epc660 chip, 320x240 pixel
- 1 LED illumination bottom side of the camera lens
- Illumination peak power ca. 2W
- 24 MHz illumination modulation frequency
- Operating range 10 ...100cm
- Calibration steps every 2cm (DRNU correction)
- Distance resolution 0.13mm
- Simultaneous acquisition of true 3D TOF and self-illuminated grayscale images
- 5 security-key images with 1GHz ARM8 processor (max. frame rate by chip in rolling mode: 158 TOF fps)

ESPROS TOF: Strengths & benefits

- High-sensitive TOF sensors (> 5x)

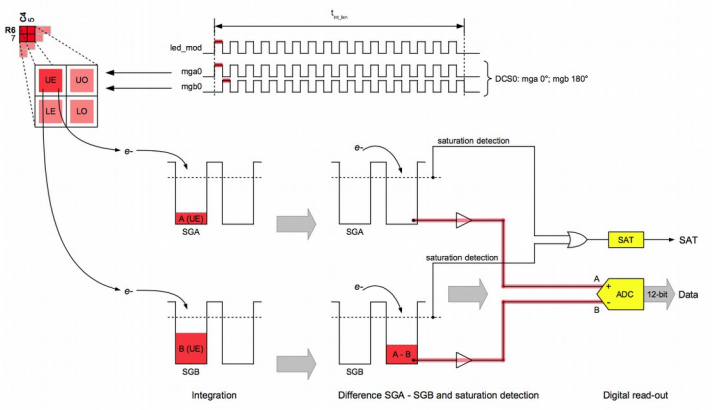
  a) 50 micron absorber
  b) 100% fill factor



---> **Low power** illumination operation

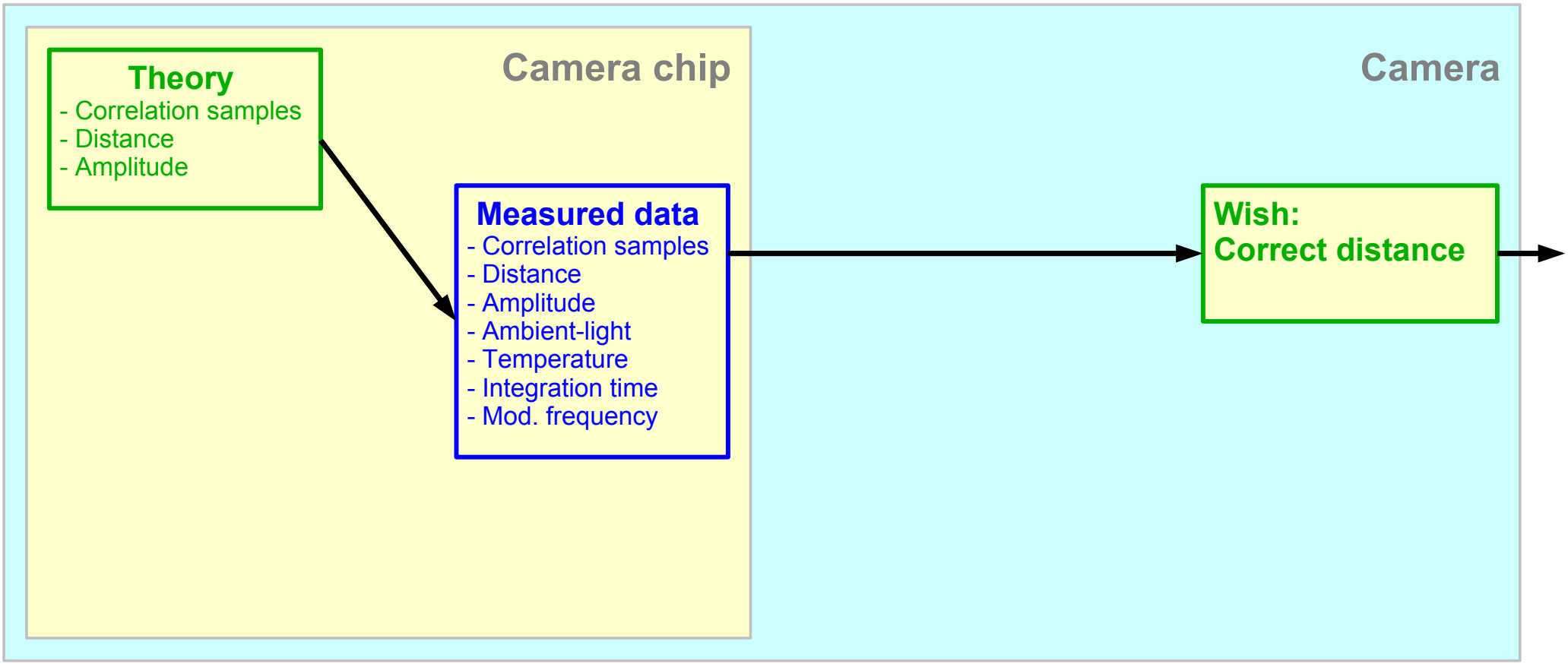
---> **Battery operation** possible

- Full ambient- / sunlight acceptance
  - 2 storage gates
  - High full well capacity
  - Differential readout
  - Ambient light suppression
  - High gain



---> More **eye safe** cameras

Formulas: Ideal 3D TOF cam



Artifacts: Real 3D TOF cam

Theory
- Correlation samples
- Distance
- Amplitude

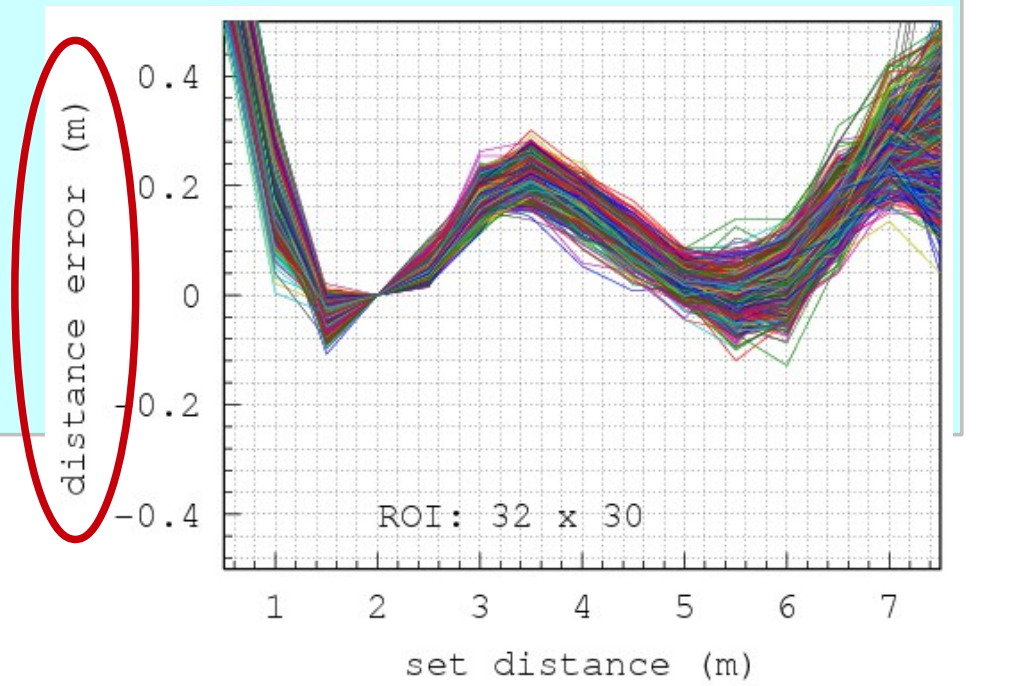
Error sources
- Modulation distortion
- Demodulation dis.
- Pixel non-linearity
- Amplitude
- Distance noise
- Fix-pattern noise
- Object reflectivity
- Ambient-light
- Temperature
- System clock
- ...

Camera chip

Measured data
- Correlation samples
- Distance
- Amplitude
- Ambient-light
- Temperature
- Integration time
- Mod. frequency

Camera

Raw distance



Error sources lead to worse results

Calibration: Intelligent 3D TOF cam

Theory
- Correlation samples
- Distance
- Amplitude

Error sources
- Modulation distortion
- Demodulation dis.
- Pixel non-linearity
- Amplitude
- Distance noise
- Fix-pattern noise
- Object reflectivity
- Ambient-light
- Temperature
- System clock
- ...

Camera chip

Measured data
- Correlation samples
- Distance
- Amplitude
- Ambient-light
- Temperature
- Integration time
- Mod. frequency

Camera

Compensation
by look-up table or algorithm
- Modulation distortion
- Demodulation distortion
- Pixel non-linearity
- Amplitude
- Distance noise
- Fix-pattern noise (FPN)
- Object reflectivity
- Ambient-light
- Temperature
- System clock
- ...

Correct distance
according the needs of the application

Sensor calibration
- Modulation distortion
- ...
- ...

Intelligent
calibration of each individual camera
and clever
image improving SW algorithms
are needed

Calibration philosophy

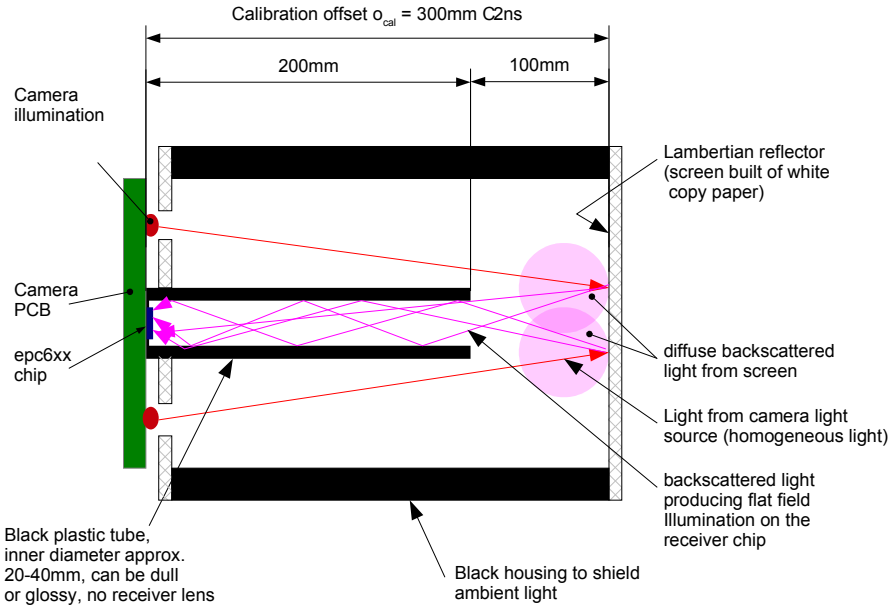
The ESPROS TOF cam calibration philosophy

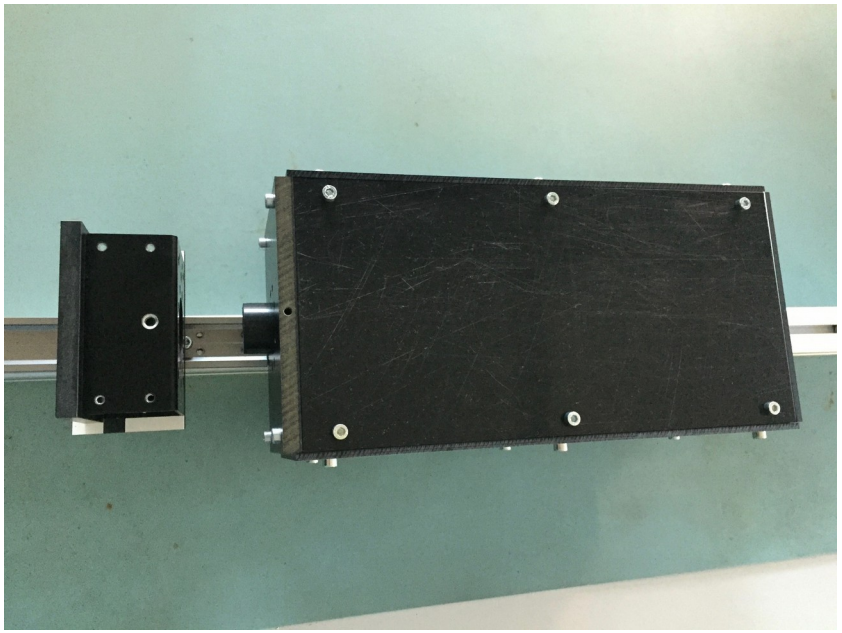
- Bulky was yesterday.
- Forget
  - (large or) wide variety of different calibration targets
  - (large) or complex calibration cabinets
  - (long) calibration rails
  - time consuming calibration procedures

- Be innovative ---> and do it the lean and sexy way

Calibration box 30 x 16 x 12 cm

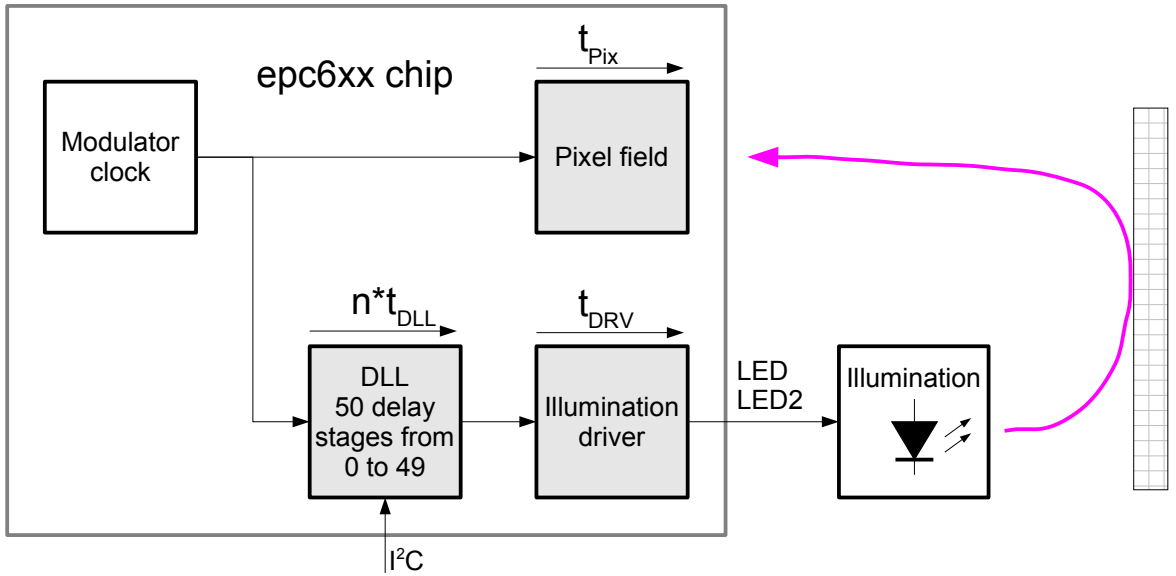
- Flat-field illumination (reflector)
- Uses the camera own illumination



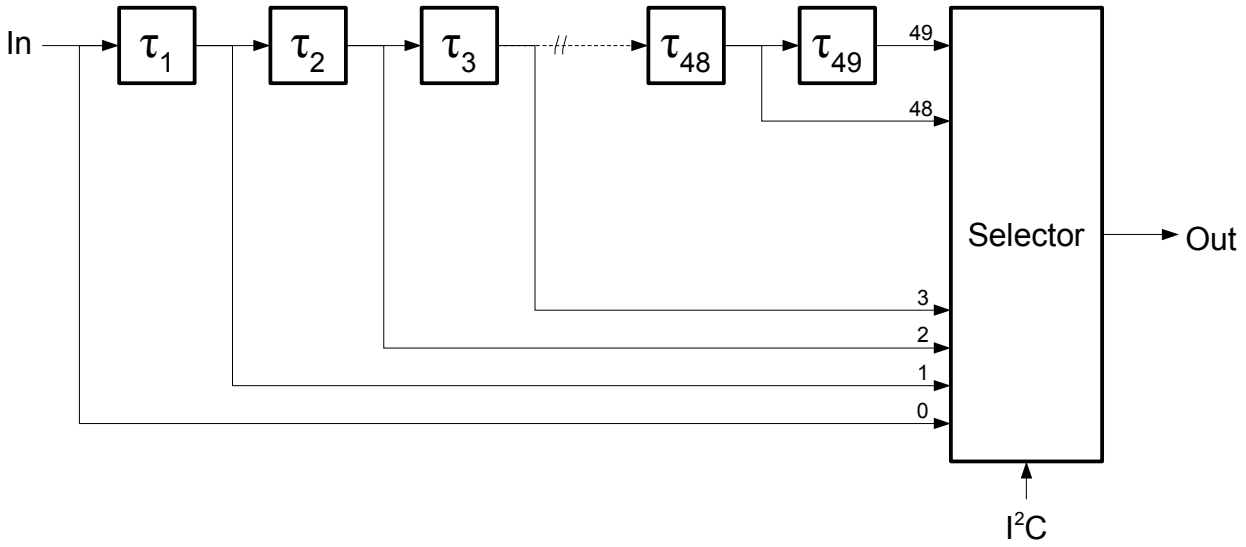


Artificial distance shift by DLL

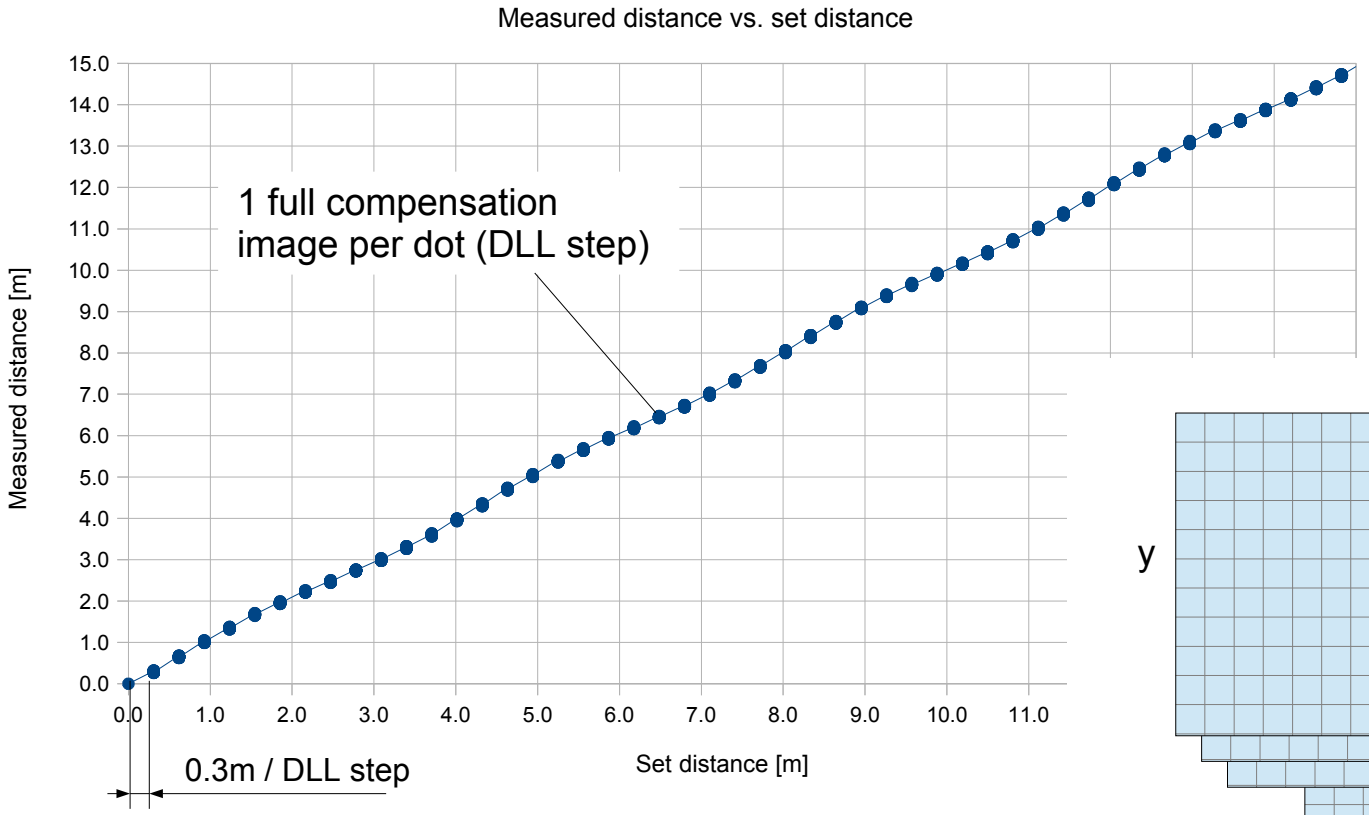
- On-chip DLL

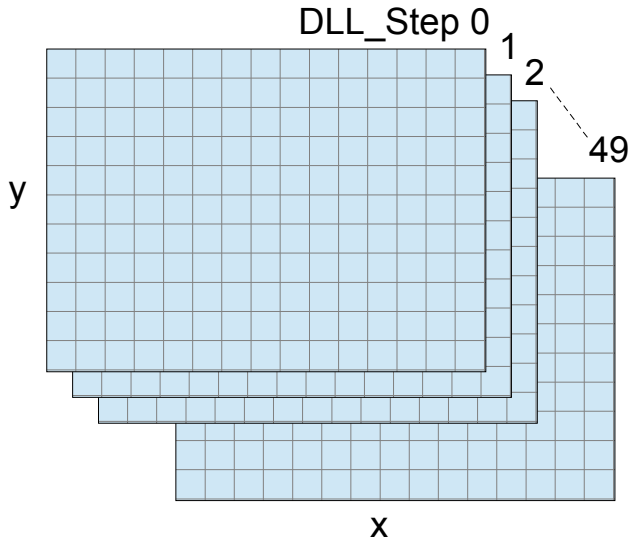


- Phase shifting by DLL e.g 50 time steps



DRNU calibration tables





ESPROS TOF cam calibration concept

Calibration:

- On-chip DLL for artificial distance shift during calibration
- Use a small, simple calibration box only with flat-field illumination (reflector)
- Distance Response Non-Uniformity (DRNU) Calibration takes DRNU calibration tables per DLL step (distance step) for each pixel of the 3D distance image

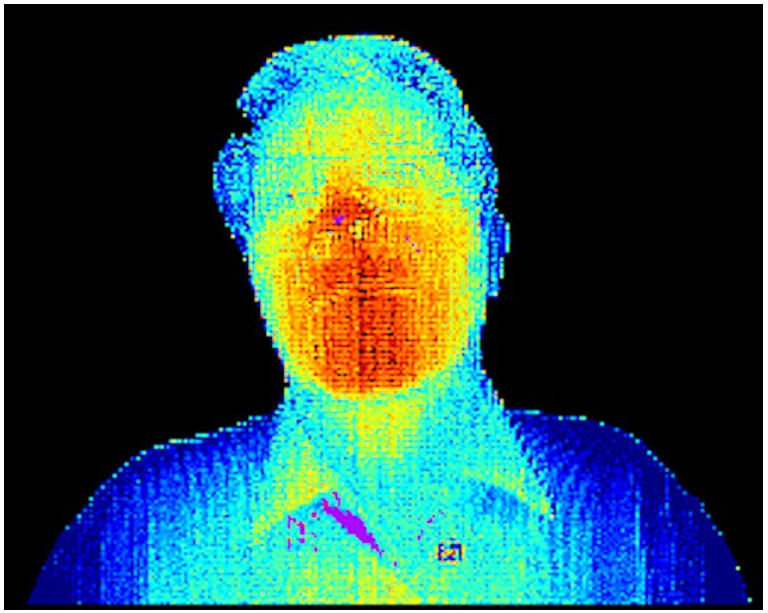
Run-time image data correction

- Apply on-the-fly DRNU correction tables, temperature compensation, etc ...

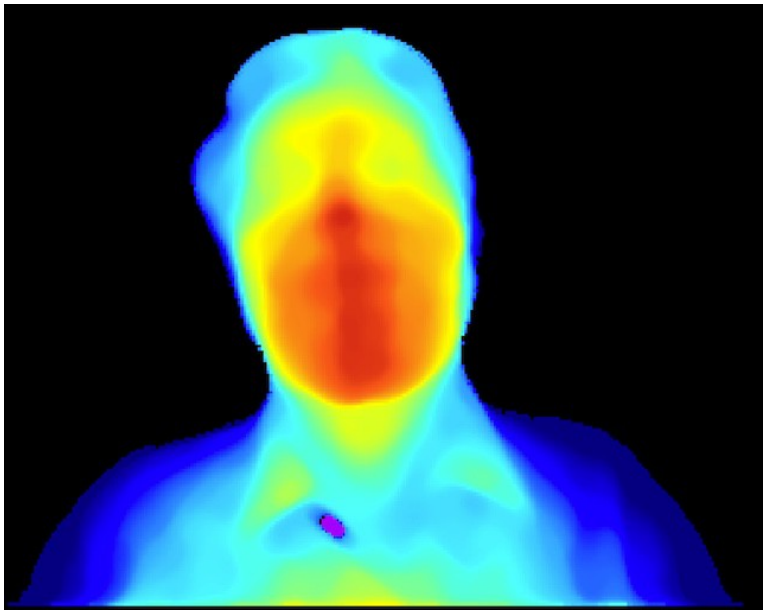
The benefit of image processing

Image processing is essential and key factor

It reduces / improves DRNU, accuracy, distance noise, edge quality, bad pixels, etc. ...



raw data



after image processing

Image processing basics

- **DRNU (linearity) correction on-the-fly**
  per pixel and per 2cm distance increment

- **Spatial filtering** (image domain)
  ---> no frame rate (fps) loss but resolution reduction
  - Median filter using recursive 5x5 pixel sliding windows
  - Gaussian filter

- **Temporal filtering** (time domain / series / sequence)
  ---> no resolution loss, but fps or response time reduction
  - Adaptive Kalman filter with threshold

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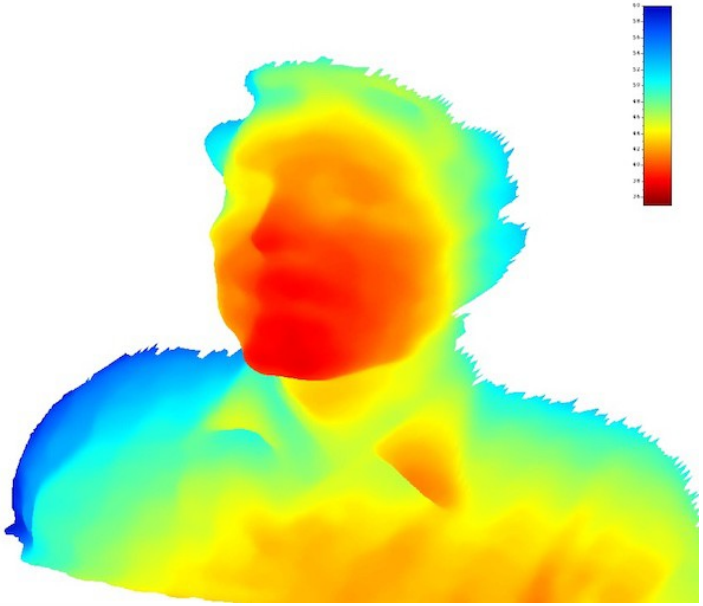
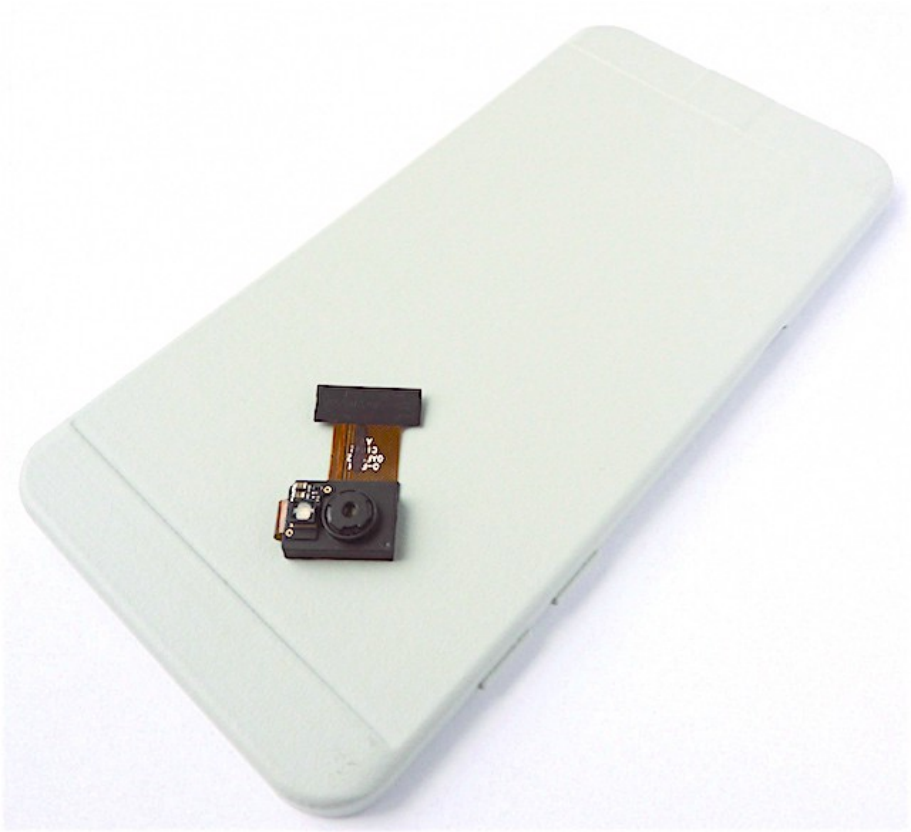
From raw data to final image

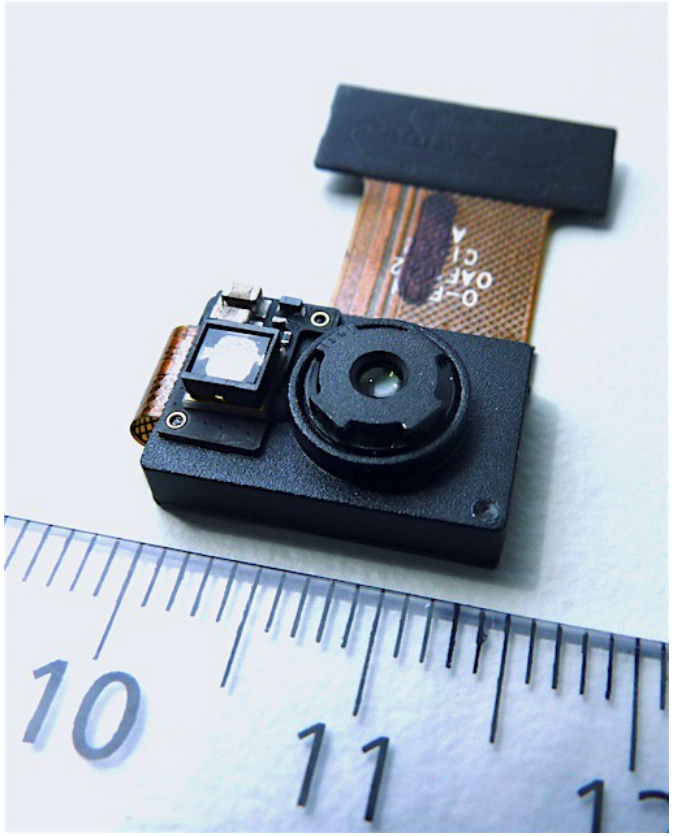


… and customer's final design

epc660 camera module

for mobile phones, tablets, screens and door access





Thank you!

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