Elaborazioni di Immagini per Dispositivi Mobile

Ing. Alessandro Capra

Advanced System Technology

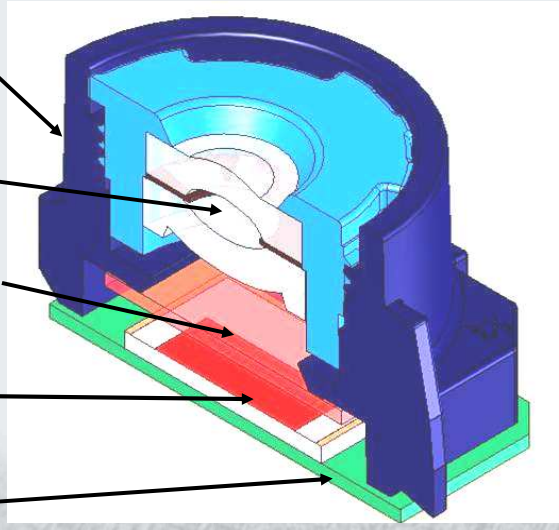
13 March 2008

STMicroelectronics

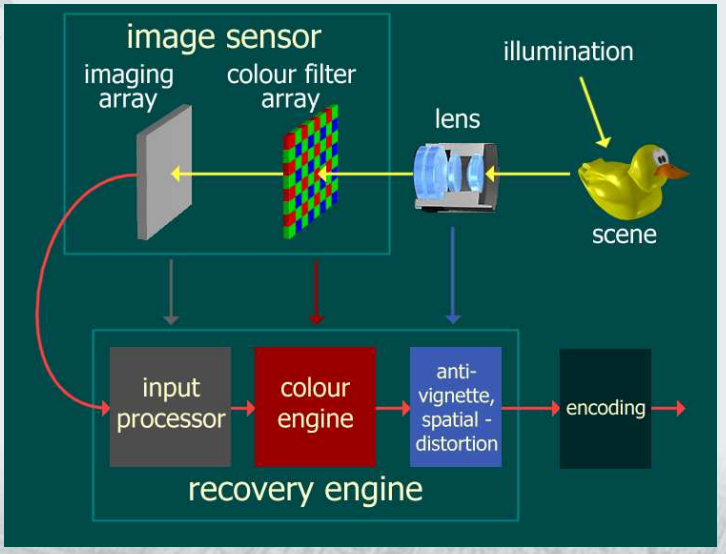
Agenda

- Introduction
- Mobile camera Devices
- Pre-processing: Auto Focus, Auto Exposure
- Color interpolation
- Color interpolation
- Noise management
- Noise estimation
- Croma management
- Codecs still/video
- Codecs still/video
- Applications
- Red eye

Miniature camera: inside view



System: The Yellow Duck



EXPOSURE CORRECTION

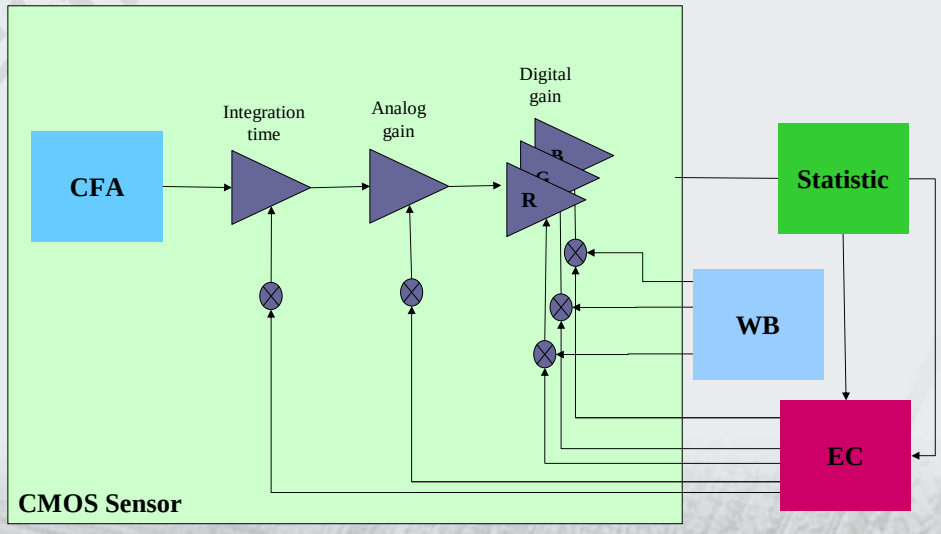
Exposure

One of main problems affecting image quality comes from improper exposure adjustment.

Most existing techniques to improve tonal quality (i.e. histogram equalization, gray level slicing…) are blind to visual content of image.

There's no way to define exactly a correct exposure but ideally most relevant features of the scene should occupy mid tone gray levels.

Exposure



Exposure

Anti Flickering Filter: reduce the light flickering during the video acquisition

$$F_{out}(t) = F_{in}(t) \cdot \frac{1}{K} + F_{out}(t-1) \cdot (1 - \frac{1}{K})$$

$$K \geq 1$$

Visibility Image 1/3

Since extraction of features can be difficult in highly underexposed or overexposed images, the mean gray level of the Y channel is forced to be ≈128.

ORIGINAL

CORRECTED

Visibility Image 2/3

Classical EC can be considered as a “roughly” correction. Correction based on relevant zones in most cases produces better results.

FLAT CORRECTION

RELEVANT ZONES CORRECTION

Computation Of Measures

Focus

$$F = \frac{\sum_{i=1}^{N} trh(|grad(i)|)}{N}$$

Contrast

$$C = \frac{\sum_{k=0}^{255} |k - M| \cdot H(k)}{\sum_{k=0}^{255} H(k)}$$

- ***N* number of pixels in the block**
- ***grad(i)* output of Laplacian (or Sobel) 3×3 filter for pixel *i***
- ***Trh* operator discards low values (noise)**

- ***M* mean gray level of block**
- ***H(k)* histogram bin for gray value *k***

Laplacian filter

0	-1	0
-1	4	-1
0	-1	0

Relevant blocks identification

All measures are normalized in the range [0:1].

Y channel

Measures on non-overlapping blocks

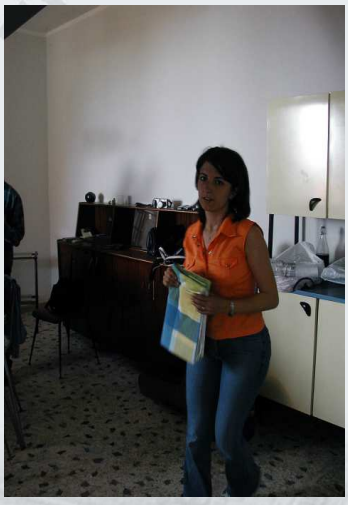
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC

Relevant blocks identification: VS=a*F+b*C>T (a+b=1)

FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC
FC	FC	FC	FC	FC	FC	FC

Relevant regions example

Examples



input

output

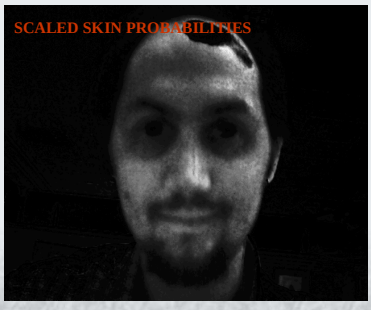
Examples

input

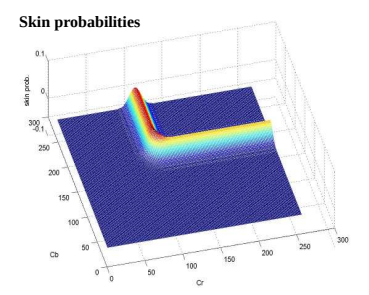
output

Skin detection 1/2

- **Probabilistic model of distribution of C_r, C_b channels used to assign reliability of skin pixels classification**
- **Pixels with probability of being skin>T are used by exposure correction**



Skin detection 2/2



Skin PDF over C_r,C_b plane can be modeled as a 2D gaussian function. Skin probabilities are well identified on chromatic plane.

$$p(\vec{x}\,|\,s)=\frac{1}{2\pi}\left|\sum\right|^{-\frac{1}{2}}exp\left\{\frac{-[d(\vec{x})]^2}{2}\right\}$$

$\sum$ covariance matrix, $\vec{x}$ chrominanc e vector

$$[d(\vec{x})]^2=(\vec{x}-\vec{\mu})'\sum^{-1}(\vec{x}-\vec{\mu})$$

$\vec{x}$ color vector, d *Mahalanobi s* metric, $\vec{u}$ mean vecto r

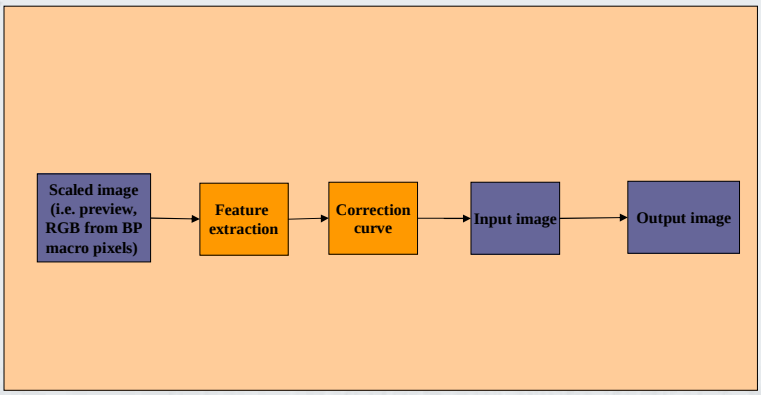
Possible solutions to reduce complexity:

1. Store portions of skin probabilities on 2D LUTS (indexed on C_r, C_b);
2. Store bounds (on C_rC_b plane) of skin region.

Example

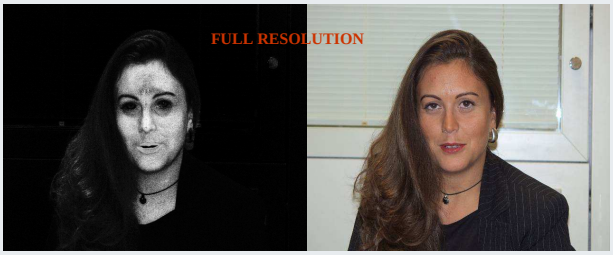
input **output**

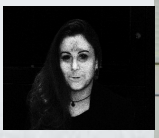
Possible speed improvement 1/3



Possible Speed improvement 2/3

Possible Speed improvement 3/3

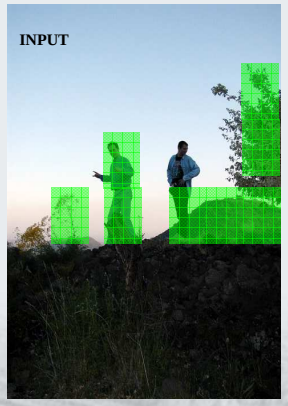


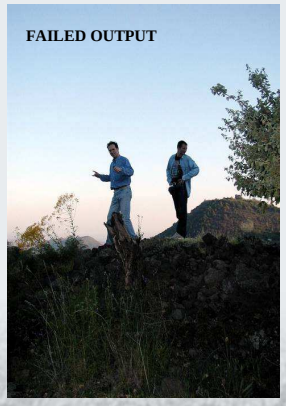


Local exposure correction

Exposure correction often works poorly especially in presence of areas of very different illumination.

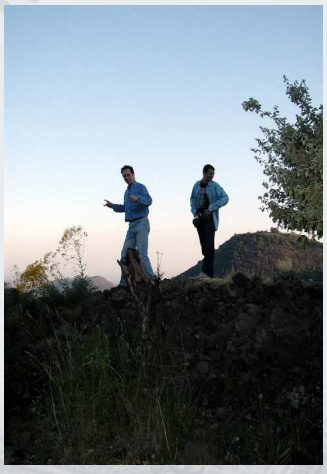
A better strategy would be applying different corrections in different areas.



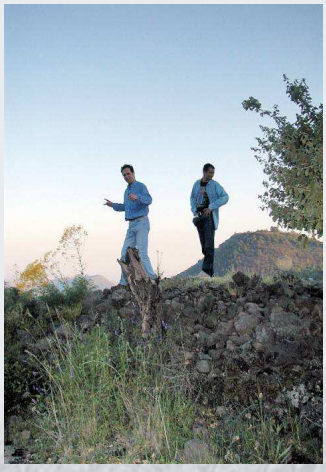


Local Correction 1/4

INPUT



OUTPUT



Local Correction 2/4

input

output

Local Correction 3/4

input

output

Local Correction 4/4

input

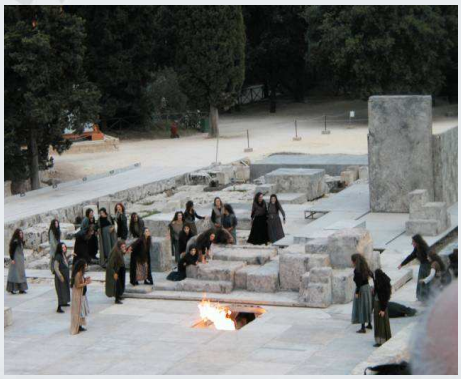
output

Comparison 1

OLD

NEW

Comparison 2



OLD

NEW

Comparison 3

OLD

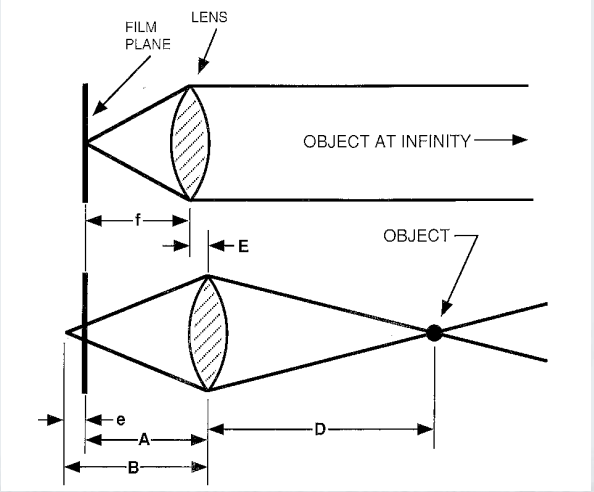
NEW

AUTOFOCUS

Optical principles

Symbol	Definition
f	Focal length of lens
A	Lens-to-film distance
B	Lens-to-sharp-image distance
D	Lens-to-object distance
E	Lens extension from infinity focus position (**E** = **B**-**f**)
e	Focus error (equal to **A**-**B** or **B**-**A**)
M	Image Magnification (**M** = **A**/**D**)

$$\frac{1}{B}+\frac{1}{D}=\frac{1}{f}$$



Optical principles

Symbol	Definition
f	Focal length of lens
N	Working f-number of the lens
d	Working diameter of the lens

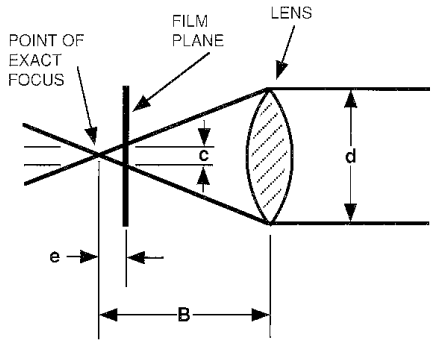
d = f/N.

$$c = \frac{e}{B}d \approx \frac{e}{f}\frac{f}{N} = \frac{e}{N}.$$

e= focus error

c= diameter of circle of confusion

g= N·max(c)



Optical principles

$$c = \frac{e}{B} d \approx \frac{e}{f} \frac{f}{N} = \frac{e}{N}.$$

$$H = f + \frac{f^2}{g}.$$

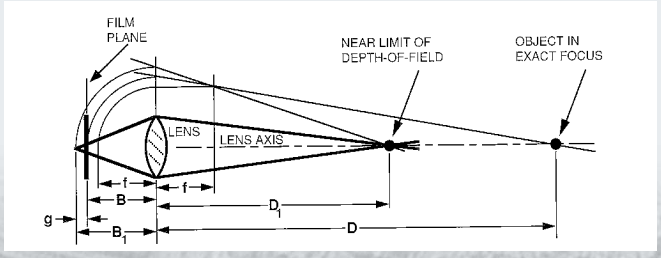
e= focus error

c= diameter of circle of confusion

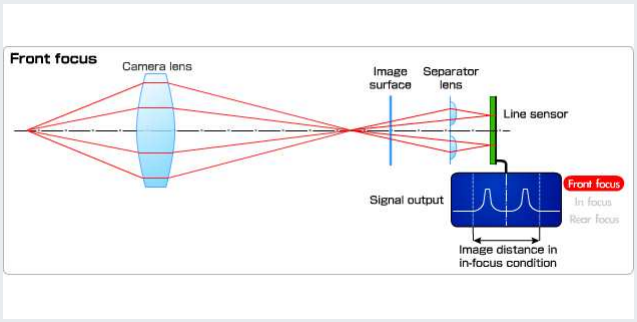
g= N·max(c)

$$D_1 = \frac{DH - f^2}{H + D - 2f} \approx \frac{DH}{H + D}$$

$$D_2 = \frac{DH - 2fD + f^2}{H - D} \approx \frac{DH}{H - D}.$$

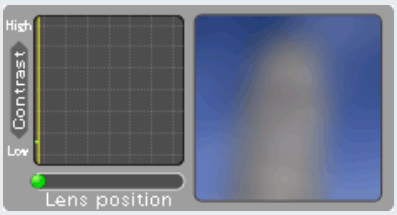


Lens: the focus system



Most **single-lens reflex** cameras use an autofocus method called the "phase detection system." Using a separator lens in autofocus module, this system produces two images from the image information of the subject captured through the lens. It then measures the distance between those two images using a line sensor, and detects defocus amount.

Lens: the focus system



Autofocus of **compact cameras** uses a mechanism called the "contrast detection system." Based on the principle that "in focus = highest contrast," this system analyzes the image information of the subject obtained by an image sensor. Then, by moving the lens, this system seeks the lens position where the image contrast is highest.

AutoFocus: Development

- What is the end-users desire?
  - To not know that an Auto-Focus algorithm is operating!
  - Perfect pictures every time at a push of a button
  - The same intelligence as you and me!!!
- Why?
  - They don't care
  - Often hi-res pictures are viewed later, they do not know the picture is in/out of focus until it is too late
  - Latency to snap is the number 1 reason for bad pictures (particularly of children and animals)
  - They think it is easy (just like their eyes) …. So do you?

AutoFocus

Requirements

- In-focus positioning related to frequency information
- Stable video focusing
- Object tracking
- Multi-objects multi-focus management
- Fast execution and low complexity

Disturbance Elements

- Light condition
- Number of edges
- Noise
- Homogeneous regions
- Motion Blur

Statistics Examples

Classical Laplacian:

$$SquareLaplaceMeasure = \sum_{x}^{n}\sum_{y}^{m} L(x,y)^2$$

$$AbsoluteLaplaceMeasure = \sum_{x}^{n}\sum_{y}^{m} |L(x,y)|$$

0	-1	0
-1	4	-1
0	-1	0

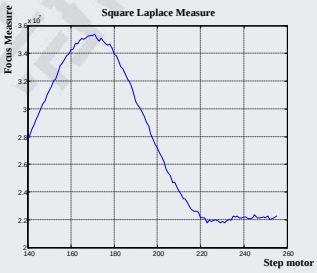
Diagonal Laplacian

$$SquareDiagonalLaplaceMeasure = \sum_{x}^{n}\sum_{y}^{m} L(x,y)^2$$

$$AbsoluteDiagonalLaplaceMeasure = \sum_{x}^{n}\sum_{y}^{m} |L(x,y)|$$

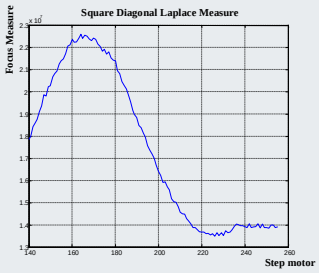
-1	0	-1
0	4	0
-1	0	-1

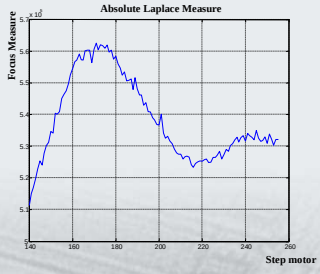
Focus Measure

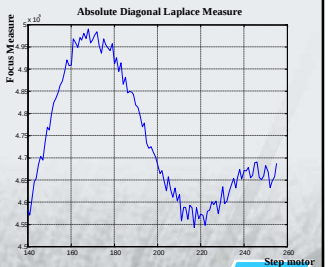


Measure window

Motor Steps

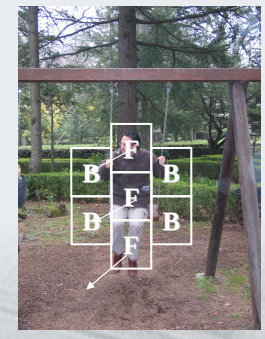




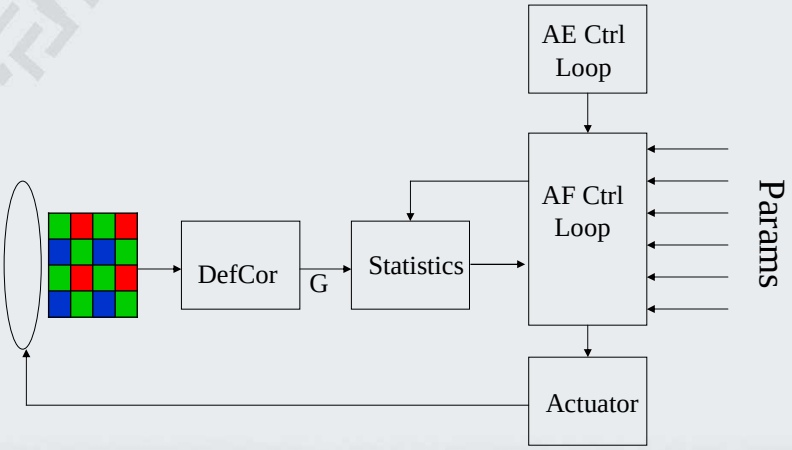


Advanced AF

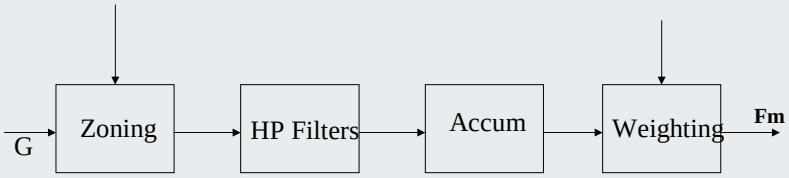
- Multi-zone analysis
- Tracking
- Object detection & Motion Analysis



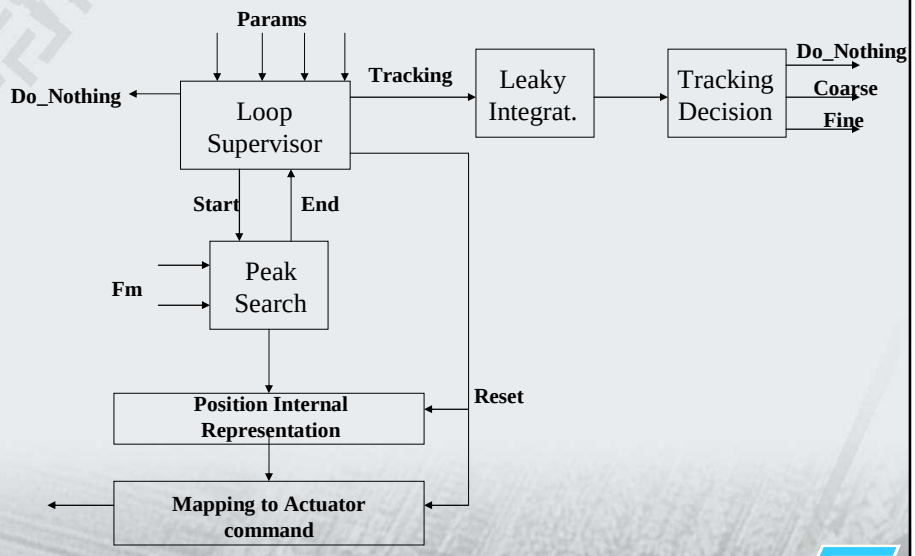
AF Functional View



Statistics



AF Control loop

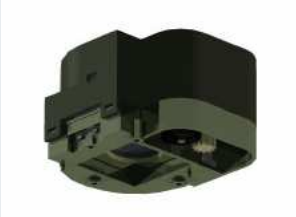


Actuator Review

Available Technologies For electro-mechanical Micro Actuation:

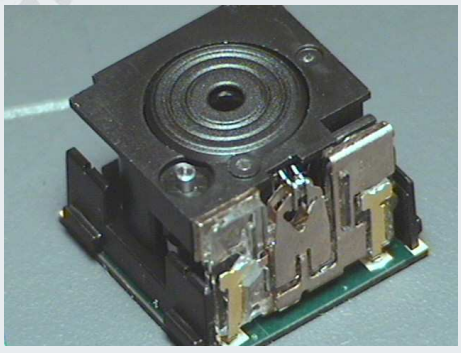
1. **Electromagnetic Actuators**
   1. Stepper Motors
   2. Simple Solenoids
   3. Voice Coil Solenoids
2. **Piezoelectric Actuators**
   1. Stacked Piezo Devices
   2. Bimorphs
   3. Disk Translators
   4. Moonie Motors
   5. Helimorphs
   6. Oscillating Bimorphs
   7. Inch Worms
   8. Ultrasonic disk motors
3. **Electrostatic Actuators**
4. **Electrostrictive Actuators**
5. **Magnetostrictive Actuators**
6. **Shape memory alloys**
7. **MEMS Actuators**

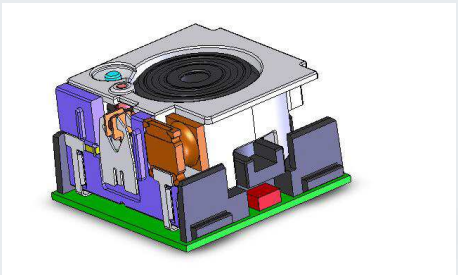
Stepper Motor: MaxEmil, ALPS



Largely used in DSC and SRL where actuator size is not relevant. Quick and precise actuator

Piezo motion solution: Miniswys





Established technologies: voice coil solution

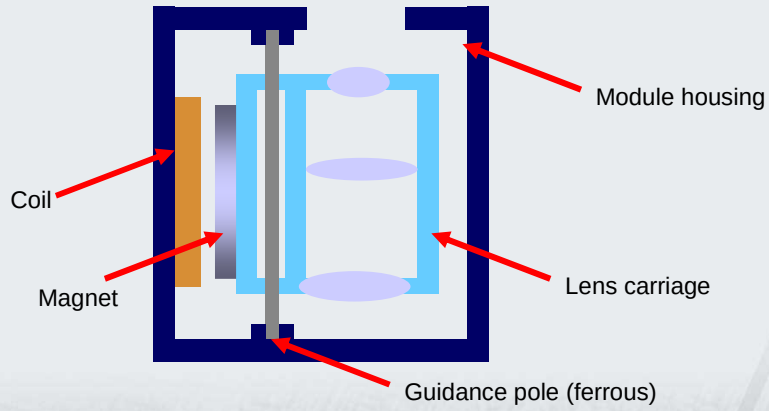
Type of motor used for most Speakers for Hi-Fi

- Used in Sony-Ericsson K750i camera phone
- Proposed by SEMCO (Samsung Electro-Mechanics)

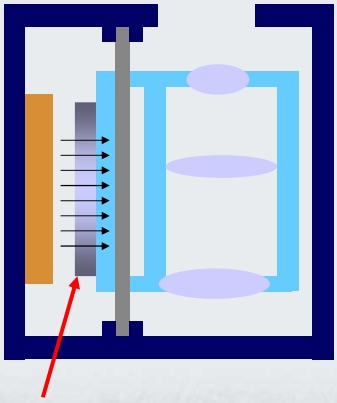
What is MSM?

- MSM is a voicecoil driven actuator with a twist – it has a static holding force
  - Technology developed by Philips Applied Technologies
  - Available to Philips High Technology plastics for use in camera modules
- A very clever and simple trick is used…

MSM concept

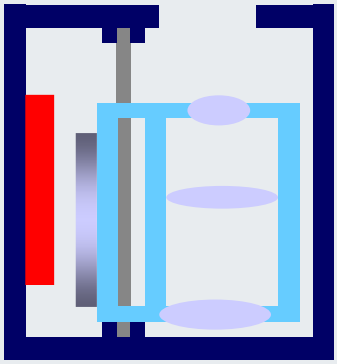


MSM concept – no current in coil



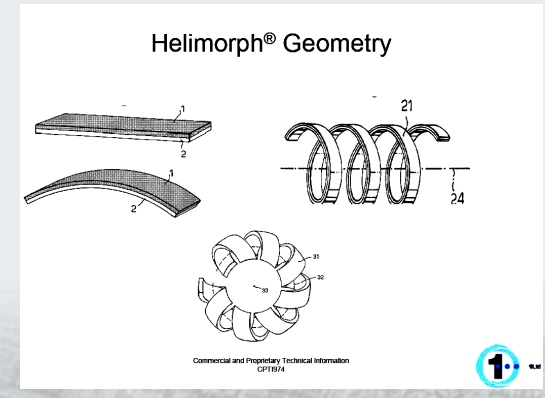
Magnet attracted to poles – holding force generated by pole/carriage friction

MSM concept – pulsed current in coil



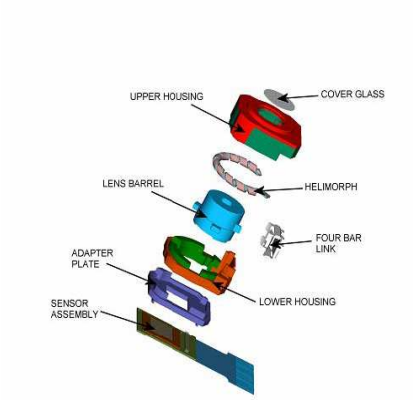
1Limited actuator

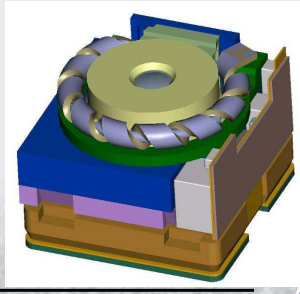
- Actuator is based on piezo in 2 or more layers
  - By putting a voltage on the layers the different expansion of the layers can cause a bend
  - 1Limited use a patented shape, the helimorph, to magnify the deflection to make it larger than a simple bender



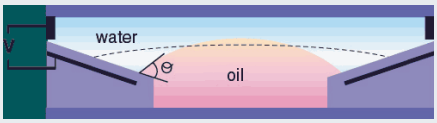
1Limited piezo design

1AF v1 - Exploded View





Electro-wetting: Varioptic



Varioptic lens technology

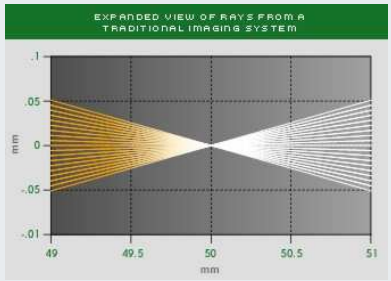
Innovative solution. Low cost and high miniaturisation. Still under development to improve speed, HQ optical response, mechanical resilience.

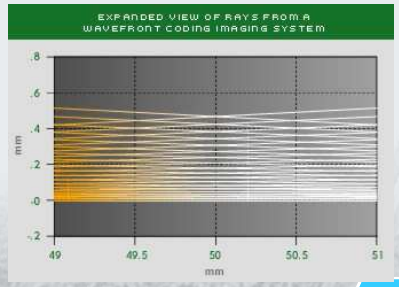
DGITAL AUTOFOCUS

CDMOptics

Improved Imaging Through Wavefront Coding™

1 WAVEFRONT CODED OPTICAL ELEMENT
2 DIGITAL DETECTOR
3 INTERMEDIATE IMAGE
4 DIGITAL PROCESSING APPLIED TO INTERMEDIATE IMAGE
5 FINAL IMAGE



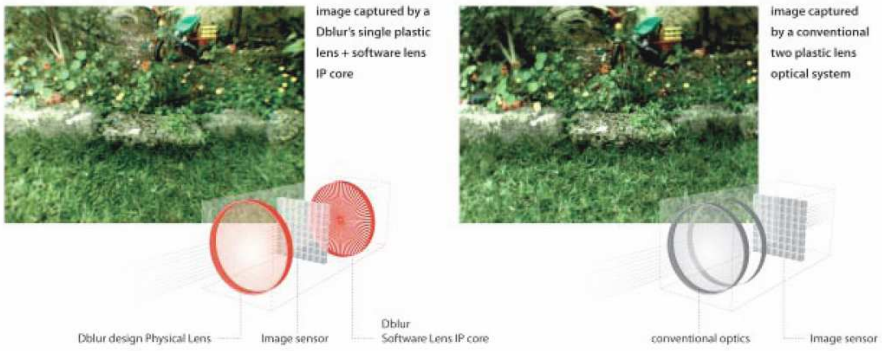


Dblur

Software Lens™ Technology

Photo Benchmarking: Dblur Vs. conventional camera module (both images captured by the same VGA 1/4" CMOS)

- Replacing conventional lens with Dblur's Software Lens IP core
- Reducing camera module cost, size and complexity



Eyesquad

- **Conventional concept**

Object → Best lens → Sensors → Processing → Image

- **Eyesquad**

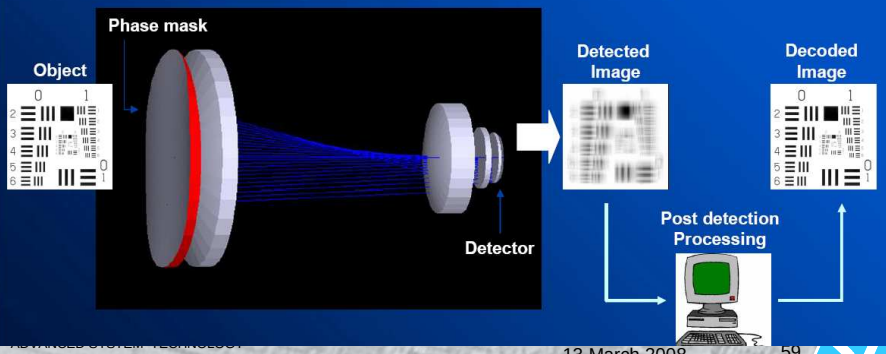
Object → Distorted lens → Sensors → Eyesquad's Processing → Image

Both parts are inter-related

Wavefront Coding

Concept

- AIM: To employ hybrid optical/digital processing to reduce COST and WEIGHT of imaging systems whilst maintaining imaging performance
  - Use wavefront coding to reduce lens count and hence weight and cost



Q&A

Bibliography

- http://www.dpreview.com
- http://www.nikon.co.jp/main/eng/portfolio/about/technology/index.htm
- http://www.canon.com/technology/index.html
- http://www.kodak.com
- http://www.learningcenter.sony.us
- http://www.st.com/stonline/products/families/imaging/imaging.htm
- http://www.samsung.com
- http://www.philips.com

- http://www.trenholm.org/hmmerk/index.html

- Image Sensor Architectures for Digital Cinematography, DALSA Digital Cinema
- Active Pixel Sensor (Aps) Design - From Pixels To Systems, Orly Yadid-Pecht
- CCD vs CMOS, Nicolas Blanc
- An advanced video camera system with robust AF, AE, and AWB control, IEEE
- Selecting the Optimal Focus Measure for Autofocusing and Depth-From-Focus, Murali Subbarao and Jenn-Kwei Tyan