BIOINSPIRED CAMERA SOLUTIONS

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Classic cameras and the human eye

model for technical imaging techniques

- Iens group
 - + aperture
 - + free space propagation
 - + detector





in reality high technical effort

- big F-numbers (bright)
- aberration correction
- dispersion correction
- optical zoom





Camera technologies

from analogue to digital image recording



instantaneous availability + extreme miniturisation

1. revolution in image recording



Miniaturized imaging systems – market





Miniaturized imaging systems – market



- 27.1 billion US\$ volume of sales 2018
- 5.1 billion units delivered in 2018
- 8.0 billion units will be estimated in 2024



cameras – quo vadis.

Year 2019:



the same old story...



Scaling of camera optics



size

costs

low angular

information

capacity

resolution

scaling limits



assumption: diffraction limited imaging





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Design criteria for imaging systems in nature... optimized for survival (reproduction) of the species

nature brain capacity optical ressources resolution 3D capability simplicity clear focus: task-orientation robustness via tolerancing compactness



Design criteria for imaging systems in nature... and analog criteria in technology

technology nature computational brain capacity power / Al optical optical ressources ressources resolution resolution economy of 3D capability simplicity **3D** capability scale compactness compactness



Imaging systems optimized for living conditions



compactness

task-orientation: eyes for hunting and gathering



Imaging systems of the jumping spyder

spyder - too small for movable single channel eyes \rightarrow 4 different, but rigid eye pairs



function principle (top view)



jumping spyder Salticidae

task-oriented eye types

- front: small field of view and high resolution
- lateral: low resolution and large field of view

task-orientation: eyes for hunting and escaping predators



Design criteria for a jumping spyders imaging system





Imaging systems for consumer electronics (VGA) rating criteria for a holistic design...





Bio inspiration...

apposition eye - daylight insects



Fruit fly drosophila



interommatidial	
angle:	$\Delta \Phi = D/R$
acceptance angle:	$\Delta \phi = [(d/f)^2 + (\lambda/D)]$
sensitivity:	$\sim d^2/(F/#)^2$
scaling:	$\Delta \Phi^2 \sim 1/R$

large field of view

. ..

- small size
- small resolution





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The dawn of multi-aperture imaging (@ IOF)

- multi-aperture camera
- "apposition eye camera"
- 110° FOV, distortion free

 small field of view per aperture (0.8°) low resolution (40 kPixel)





IOF 2006



Production of the electronic apposition eye



wafer with 5x5 multi-aperture optics

standard lens faceted eye lens





ultrathin camera

multi-aperture optics connected with CMOS sensor in ceramic housing





Imaging systems for consumer electronics (MP) rating criteria for a holistic design...





Bio inspiration

superposition eye – Xenos parasite

Xenos peckii





scheme of Xenos peckii's eye

- many different eyes with different viewing directions
- fractions of the object on each part of the retina (ommatidium)
- image rotation and stitching in the "brain"



Production of the electronic cluster eye





Electronic cluster eye – image reconstruction





Test images



captured image of test target



image captured outside the institute



image to determine distortion



video captured with prototype



Electronic cluster eye map of depth







Electronic cluster eye

software-refocusing









See the world with different eyes...

facetvision.de





Optics is per definition bidirectional...





The inverted cluster eye – the array projector

- optics setup analogous to focused fly's eye condenser buried slide array (object array)
- projection distance determined by pitch difference between slide and projection lens array





Ultrathin projectors

- LCD array projector
- LCoS array projector
- OLED array projector









insect-inspired projection

Imaging systems for consumer electronics (20 MP+++) rating criteria for a holistic design...





> 20MP camera – the hybrid / the best from two worlds...





