Computer Vision

Lecture 1: Introduction and Course Overview

Oliver Bimber

JOHANNES KEPLER
UNIVERSITY LINZ

New Computer Vision Lecture and Labs

- **Lecture**
  - Online only (+ Recordings and Slides)
  - No Attendance required (but highly recommended)
  - ML Focus
  - Application-Oriented rather than Theory-Oriented (reduced Math)

- **Labs**
  - Online only (+ Recordings, Slides, Code of Assignments and Model-Solutions)
  - No Attendance required (but highly recommended)
  - 2 Onboarding Labs (Basic Image Handling and Machine Learning in Python)
  - 4 Individual Assignments related to Lecture Topics
  - 2 Open-Labs during Assignments (for Q&A and Problems)

Who We Are

ICG

The Institute

We do Visual Computing!

Website: www.jku.at/cg

COMPUTER VISION & GRAPHICS

Computational Imaging
Machine Learning
Intelligent Optics

Oliver Bimber

VISUAL DATA SCIENCE

Visualization
Visual Analytics
Explainable AI

Marc Streit

GAME COMPUTING

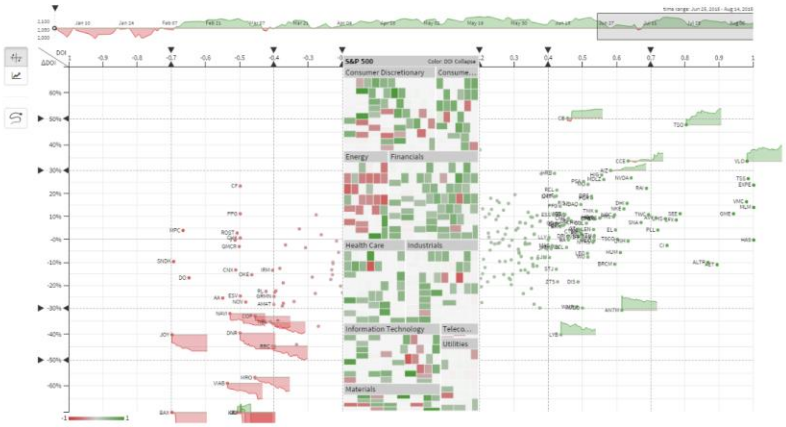
Games User Research & Analytics
Gameplay Visualization
AI-based Playtesting

Günter Wallner

Who We Are

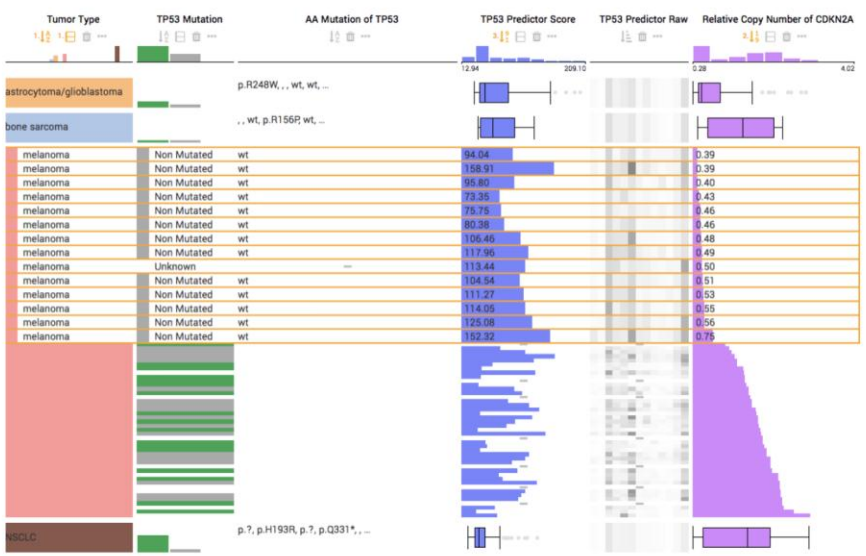
ICG

JKU Visual Data Science Lab



Research Areas:

Visualization
Visual Analytics
Explainable AI
Biological Data Vis

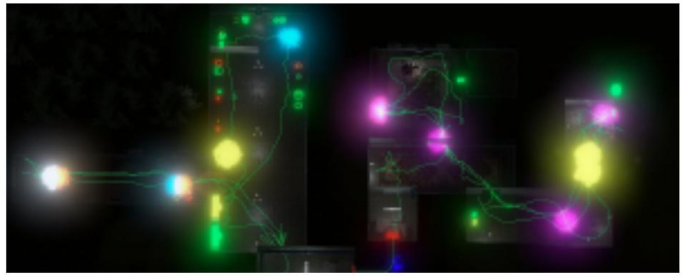


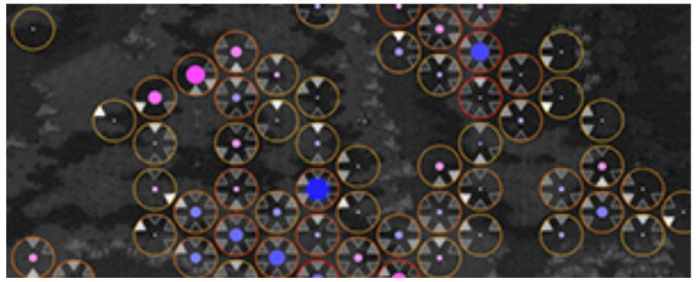
marc.streit@jku.at

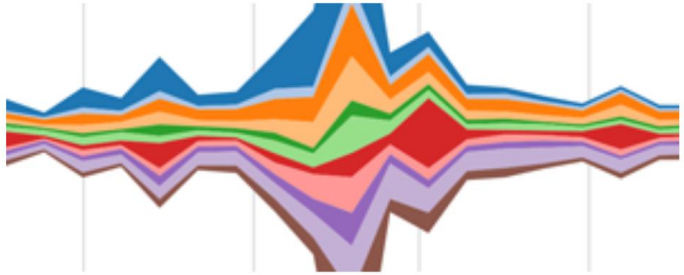
JOHANNES KEPLER UNIVERSITY LINZ

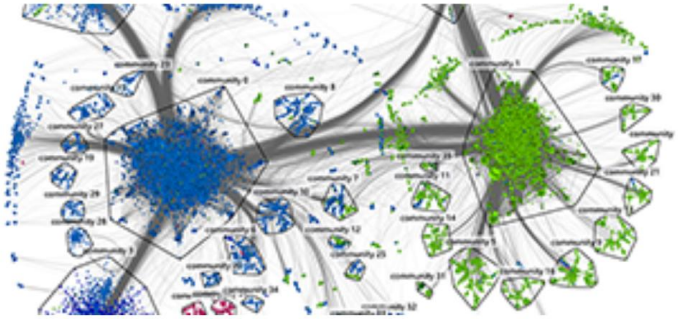
Who We Are

ICG









Research Areas:

Games User Research
Games Analytics
Gameplay Visualization
AI-based Playtesting

guenter.wallner@jku.at

JOHANNES KEPLER UNIVERSITY LINZ

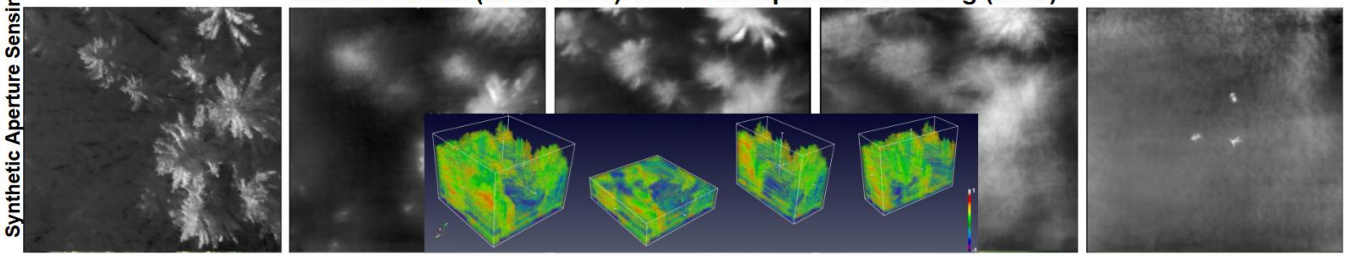
Who We Are

ICG

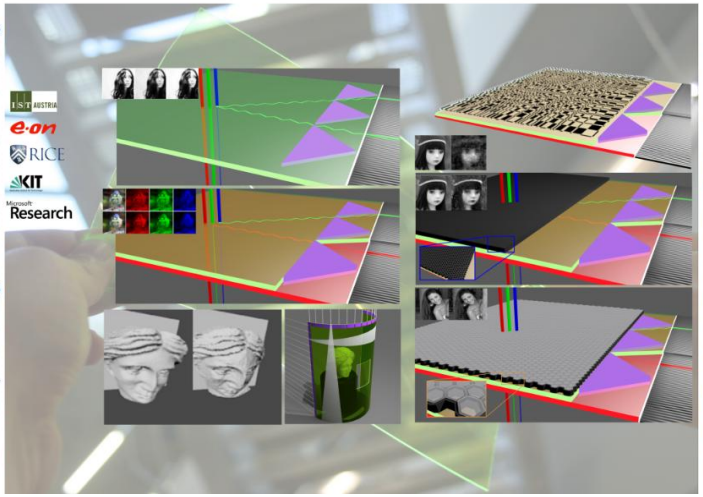
Basic Research: Light Fields
Disciplines:
Computational Imaging & Optics
Computer Vision / Image Processing
Areas:
Aerial Imaging, Microscopy, Thin-Film Sensing, 3D Displays, Autonomous Drones and Swarms
Applications:
Search and Rescue, Wildlife Observation, Wildfire Detection, Forest Ecology, Agriculture, Optogenetics, User Interfaces

Current Focus (since 2018): Airborne Optical Sectioning (AOS)

Aerial Light Fields: Synthetic Aperture Sensing



2D-Transported Light Fields: Thin-Film Sensing



Illumination Light Fields: Light-Field Microscopy

Publications: Nature Machine Learning, Science Robotics, Nature Communications Engineering,IEEE, ACM, …

Funding: FWF, DFG, Upper Austria, LIT, EU, Microsoft Research, FFG, Helmholtz Association, Nokia, e.on, …

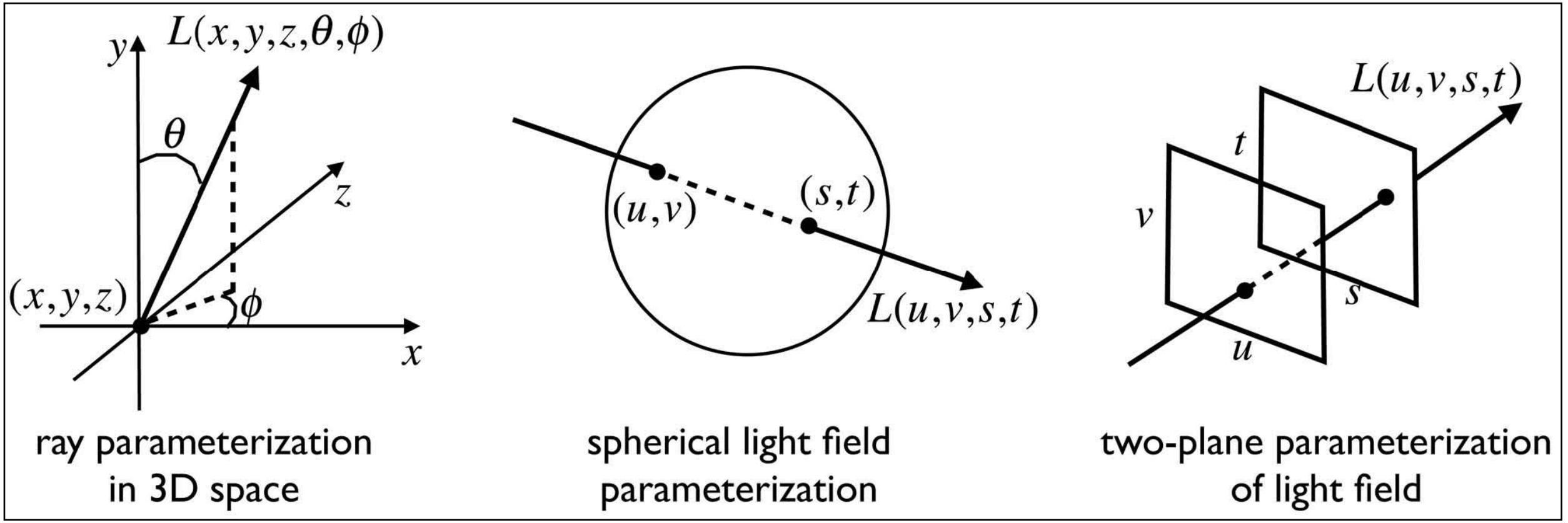
Current Collaborators: Cambridge U., EPFL, DLR, BOKU, OOELFV, U. Magdeburg, Helmholtz UFZ, U. Bozen, …

oliver.bimber@jku.at

INSTITUTE OF COMPUTER GRAPHICS

JOHANNES KEPLER UNIVERSITY LINZ

Light Fields in a Nutshell

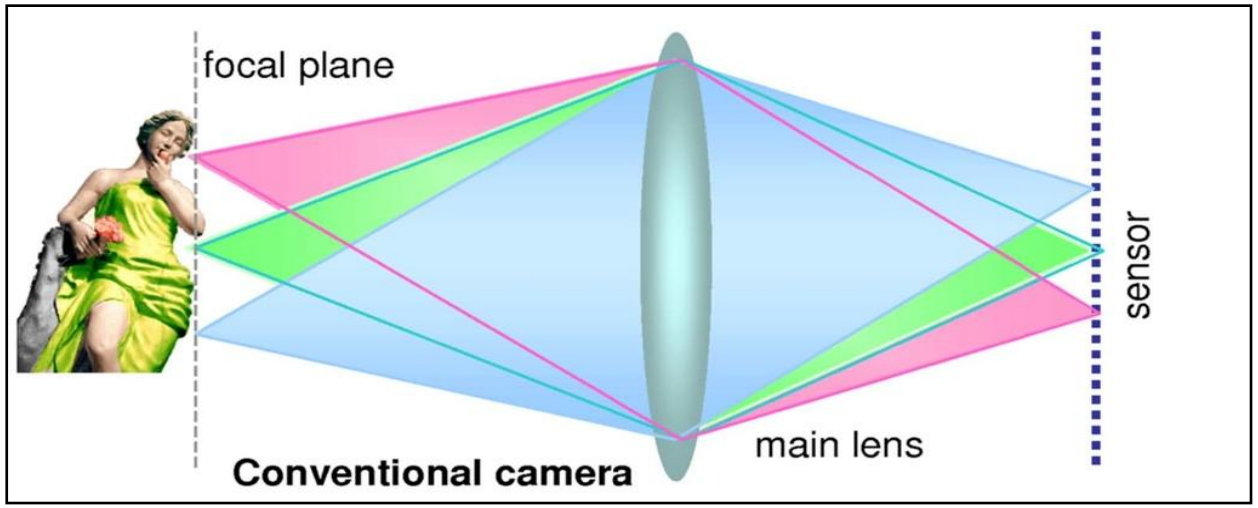


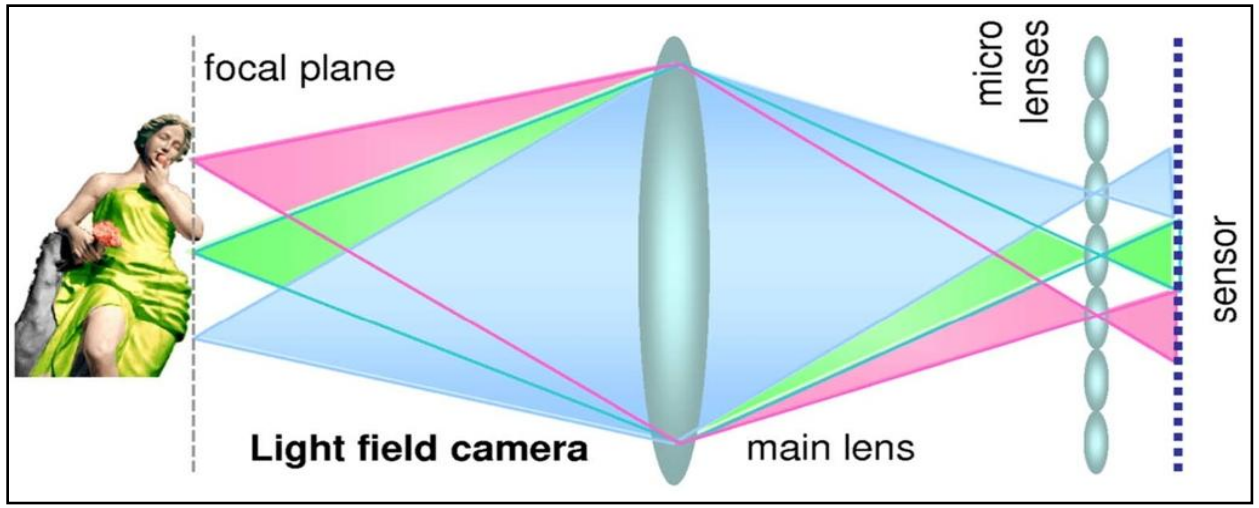
ray parameterization in 3D space

spherical light field parameterization

two-plane parameterization of light field

Light Fields in a Nutshell



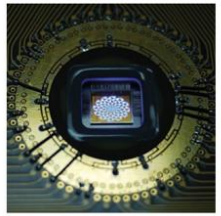


Lytro
(omnidirectional camera array)

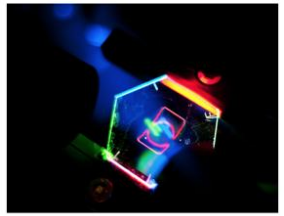
Lytro
(equifocal microlenses)

Pelican Imaging
(camera array)

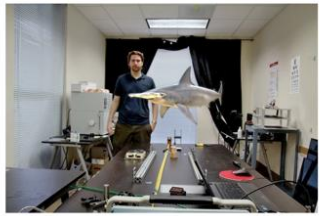
Raytrix
(multifocal micro lenses)



Ostendo
(quantum photonic imager)



Hewlett Packard
(multi-directional backlight)

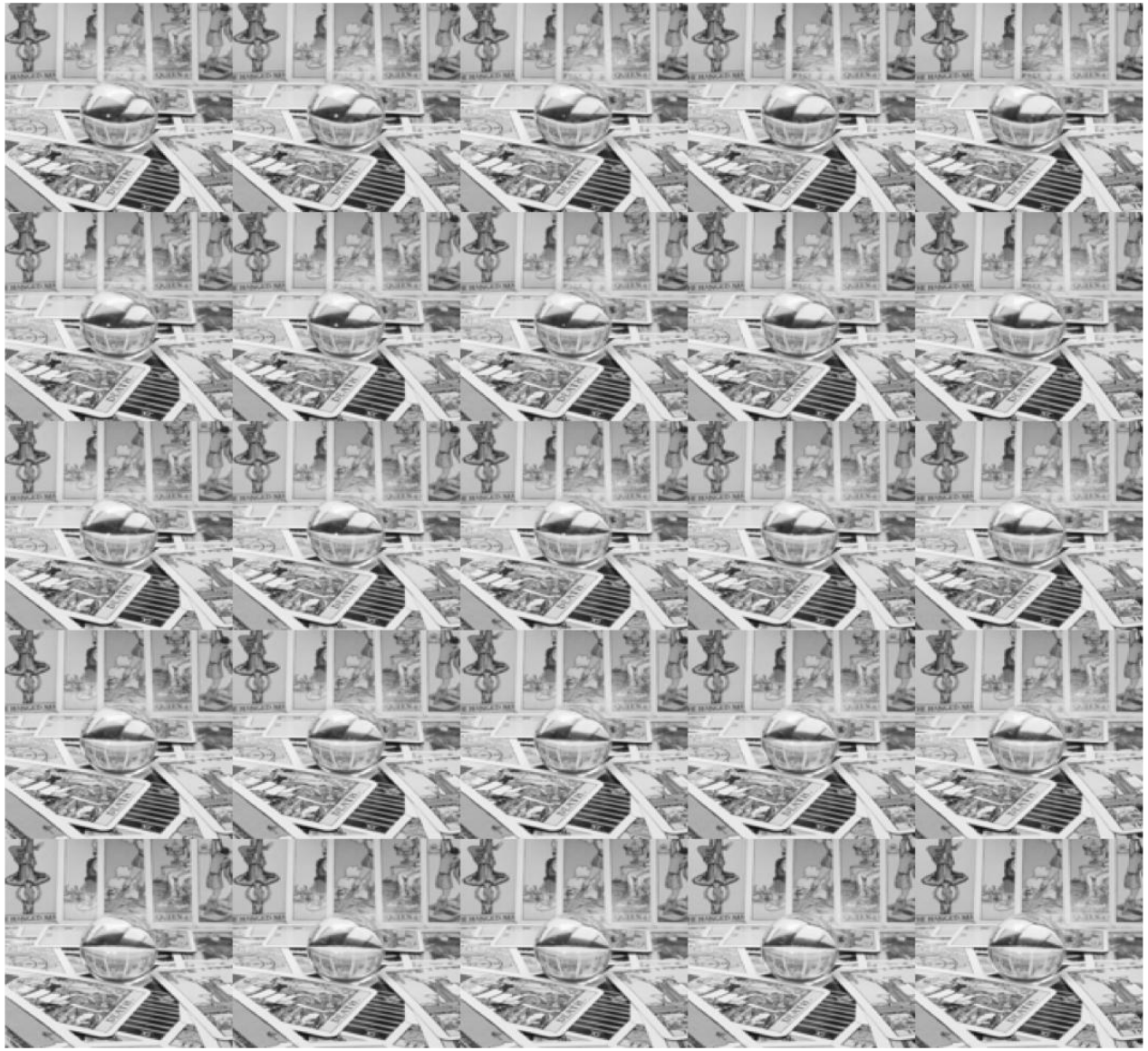


Magic Leap
(scanning optical fibers ?)

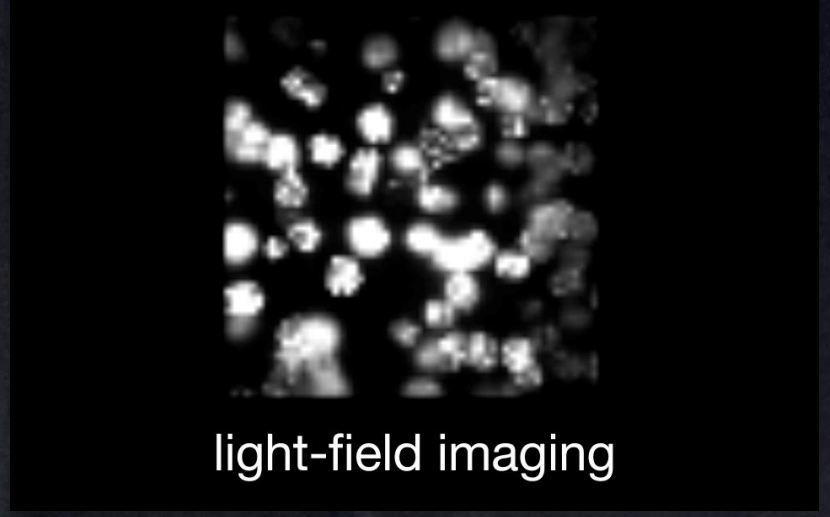
Light Fields in a Nutshell

JOHANNES KEPLER UNIVERSITY LINZ

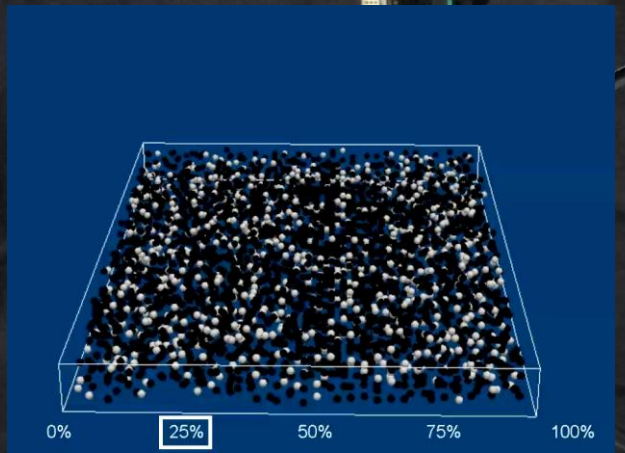
Light field: spatial resolution outside, angular resolution insight.

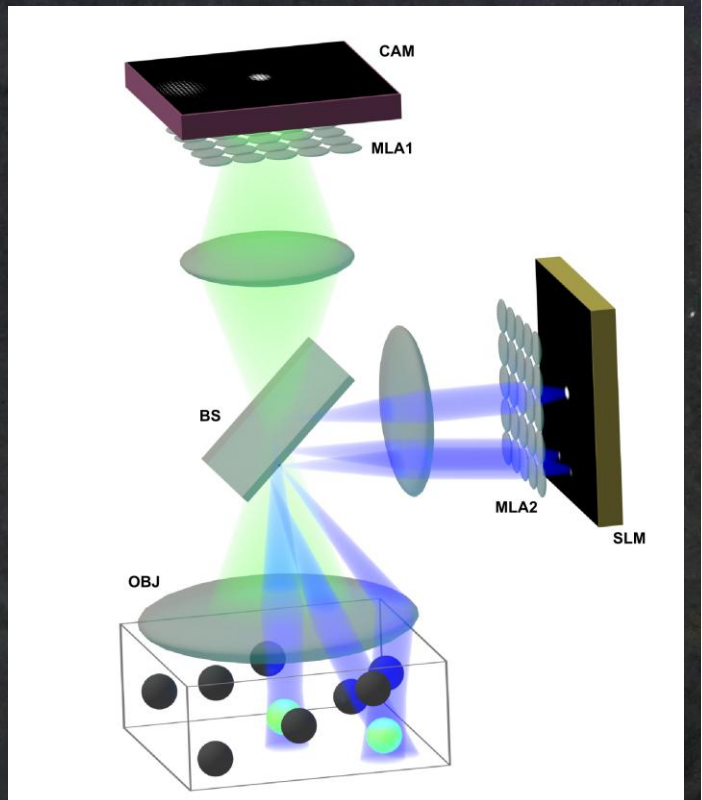


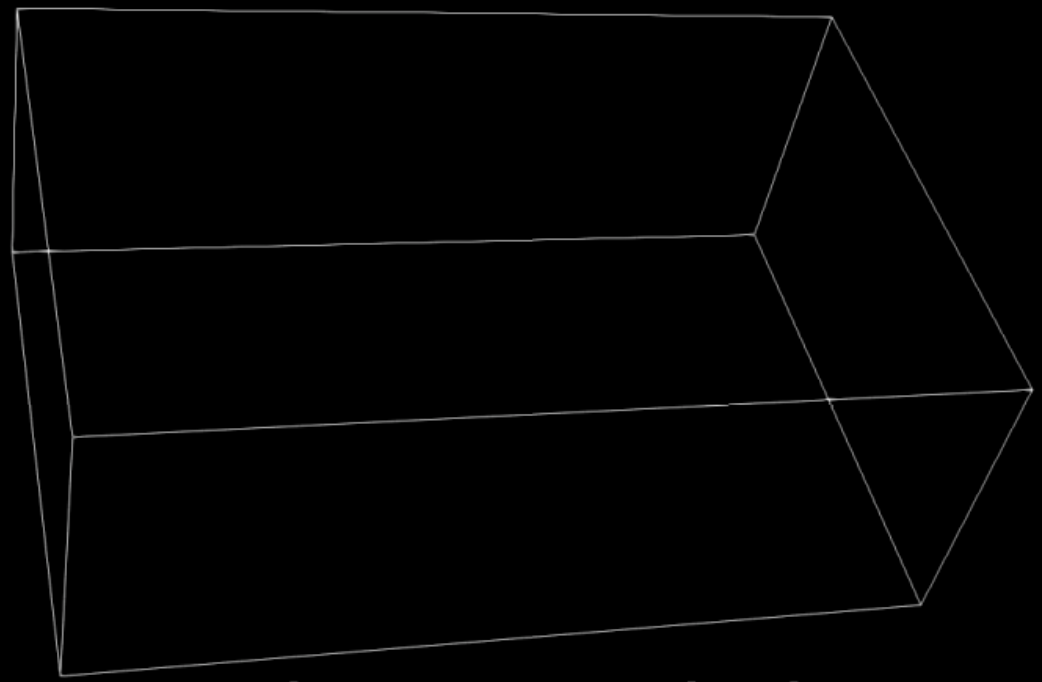
Light field: angular resolution outside, spatial resolution insight.



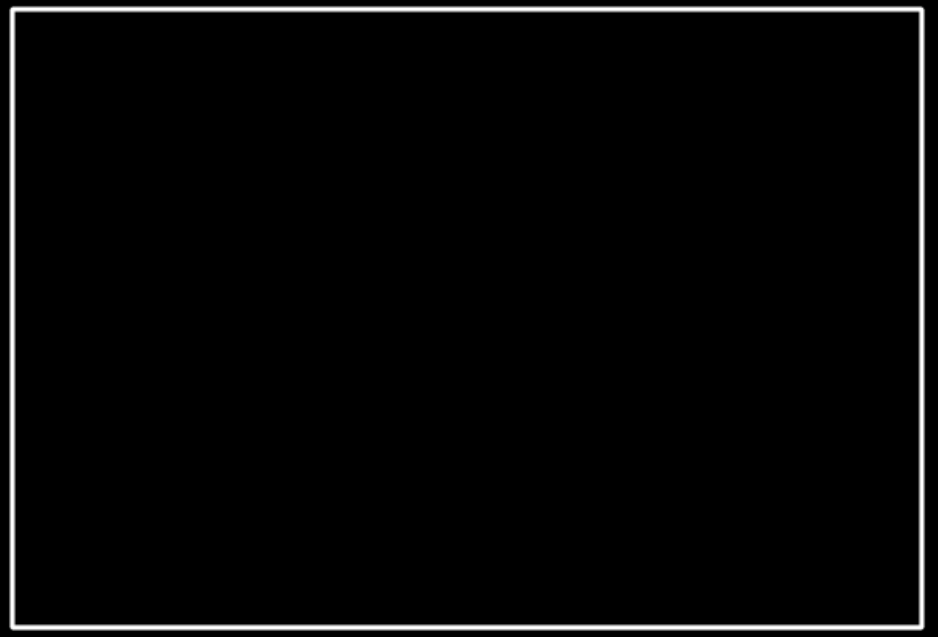
light-field imaging



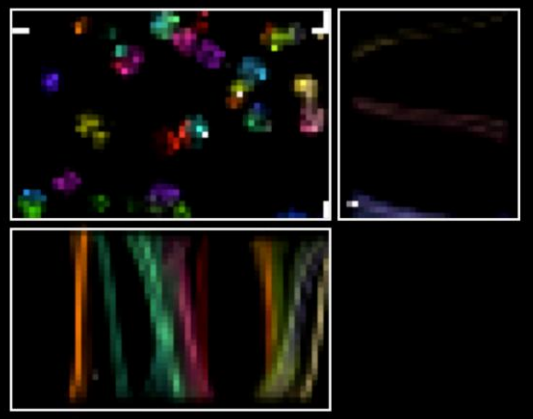




volume rendering



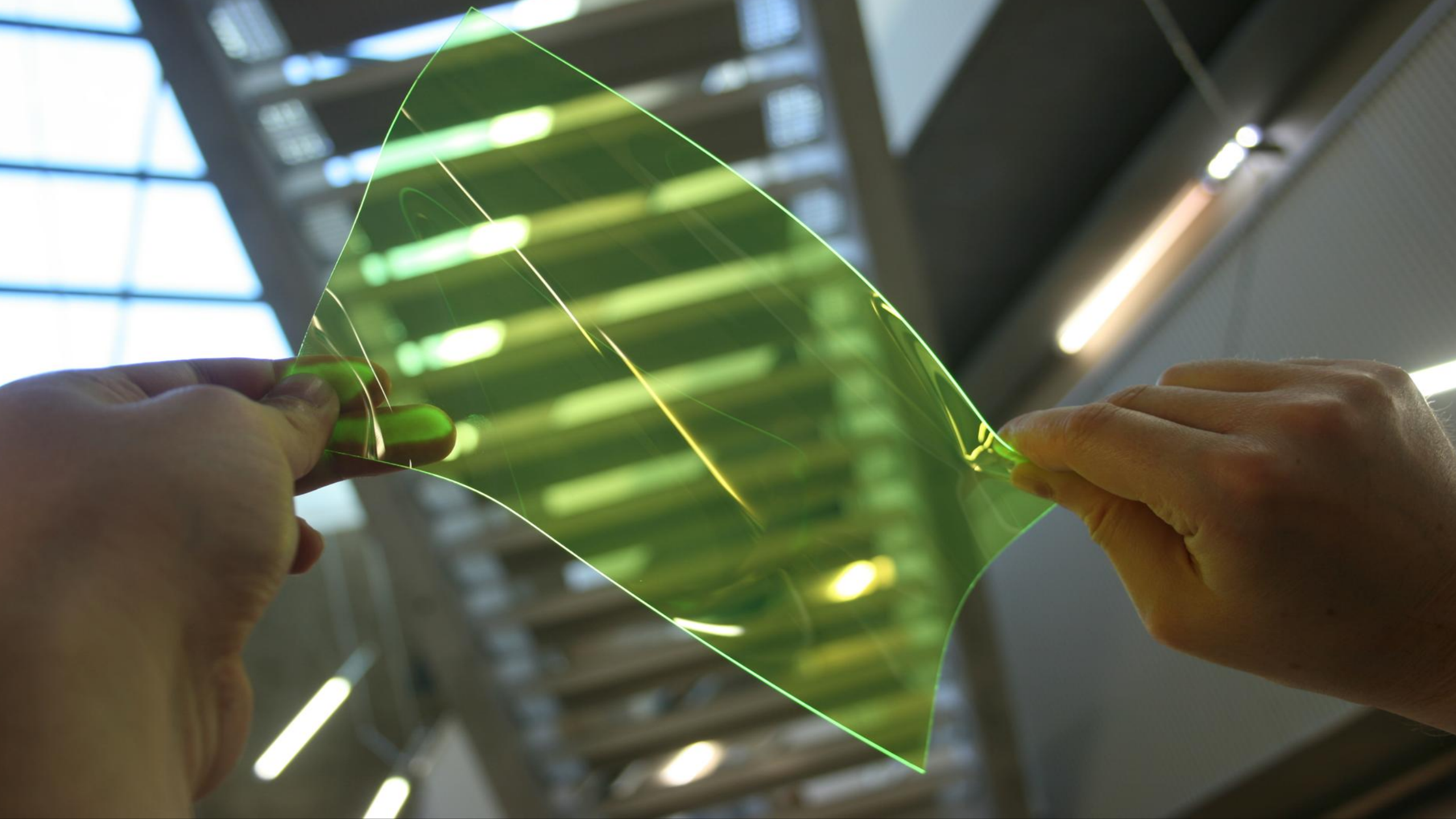
selected particle signatures

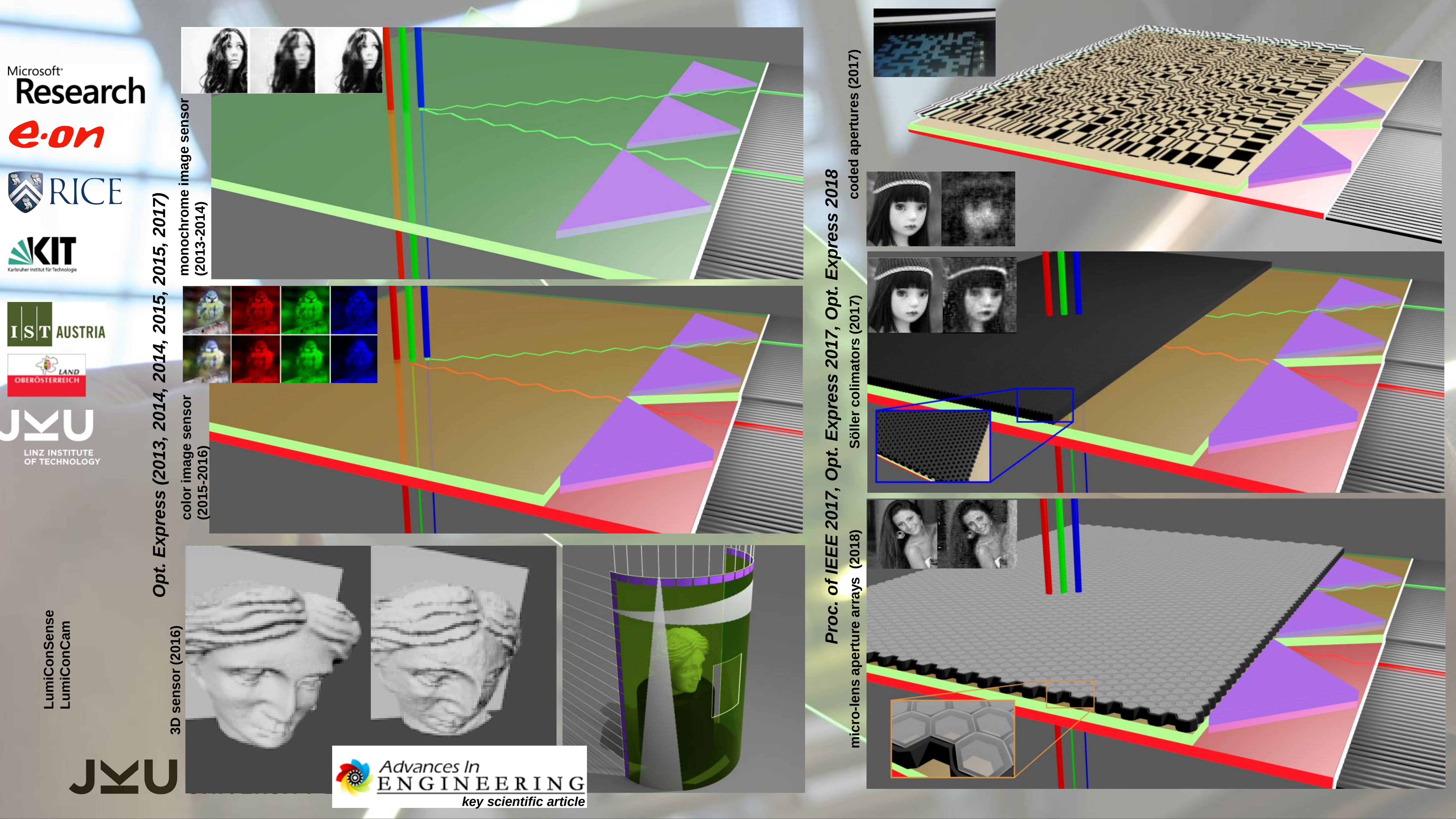


Compressive
Volumetric Light-Field Excitation

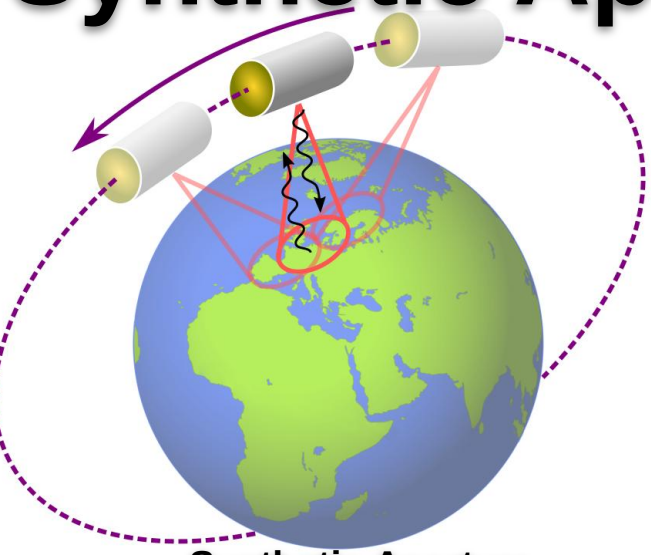
Nature Sci. Rep. (2016, 2017)

JOHANNES KEPLER UNIVERSITY LINZ

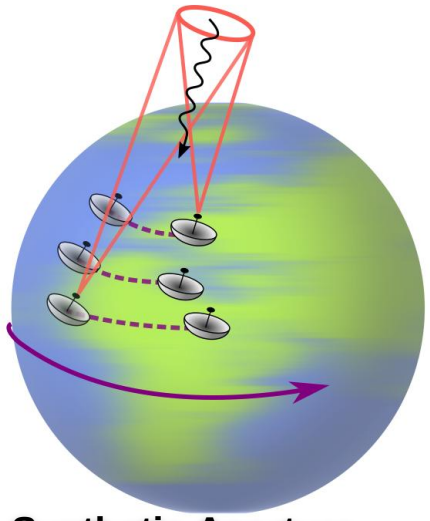



Microsoft Research
e·on
RICE
KIT
Karlsruher Institut für Technologie
IST AUSTRIA
LAND OBERÖSTERREICH
JKU
LINZ INSTITUTE OF TECHNOLOGY
LumiConSense
LumiConCam
JKU
Opt. Express (2013, 2014, 2014, 2015, 2015, 2017)
monochrome image sensor (2013-2014)
color image sensor (2015-2016)
3D sensor (2016)
Advances In ENGINEERING
key scientific article
Proc. of IEEE 2017, Opt. Express 2017, Opt. Express 2018
coded apertures (2017)
Söller colimators (2017)
micro-lens aperture arrays (2018)

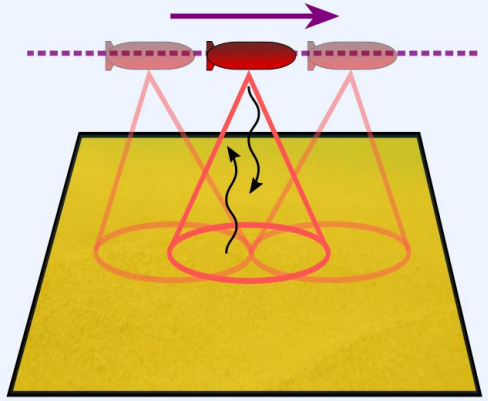
Synthetic Aperture Sensing



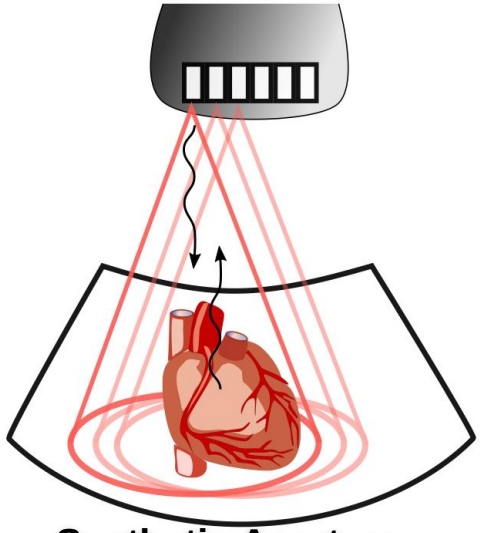
Synthetic Aperture Radar (SAR)



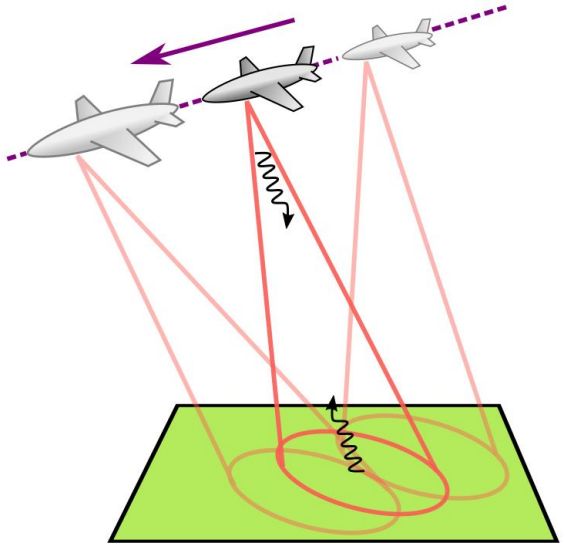
Synthetic Aperture Radio Telescopes (SART)



Synthetic Aperture Sonar (SAS)

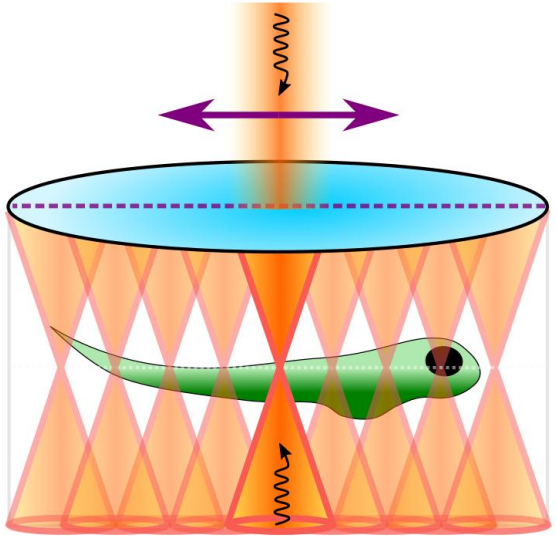


Synthetic Aperture Ultrasound (SAU)

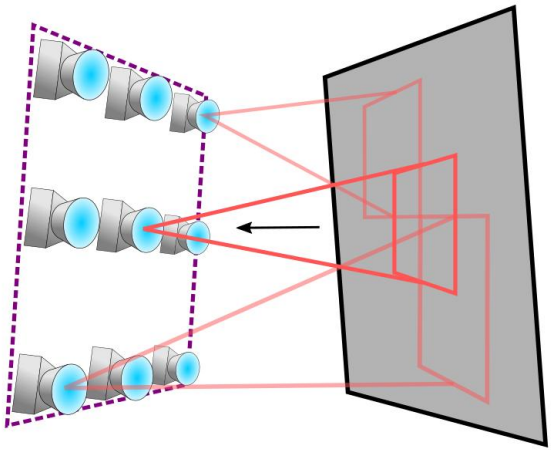


synthetic aperture LiDAR (SAL)

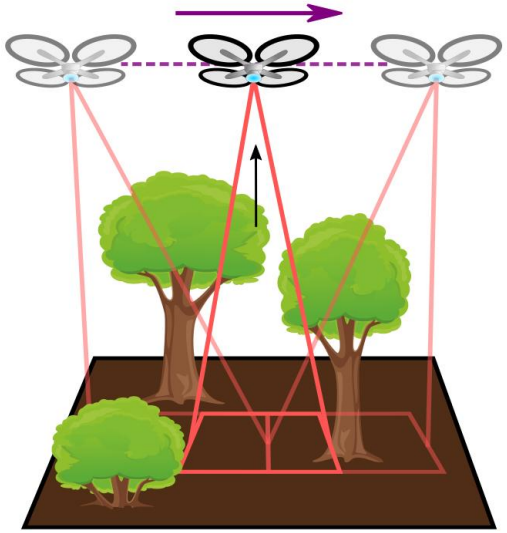
synthetic aperture imaging laser (SAIL)



Interferometric Synthetic Aperture Microscopy (ISAM)



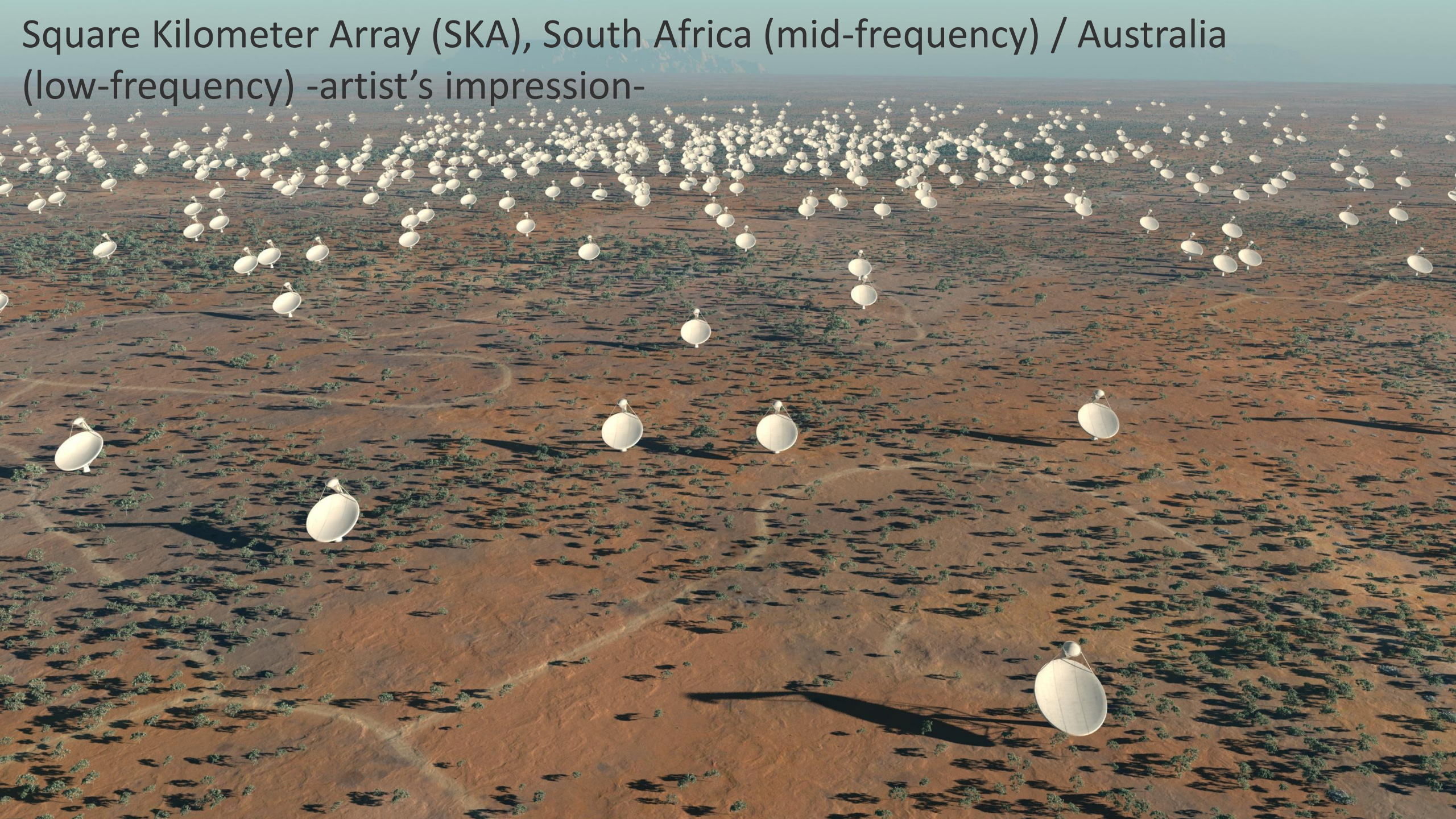
Structured Light-Field Imaging (SLFI)



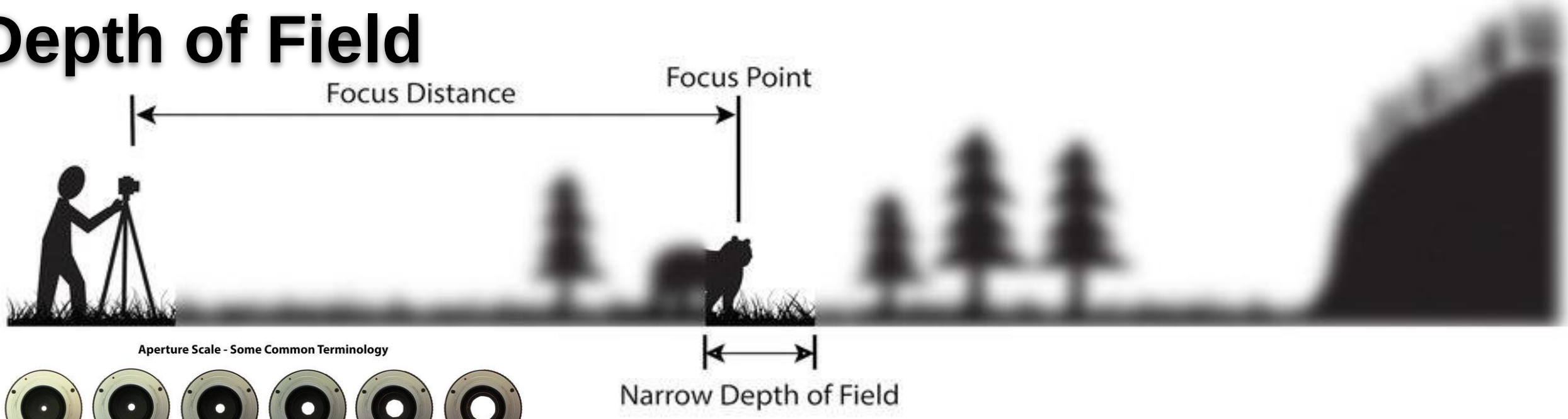
Airborne Optical Sectioning

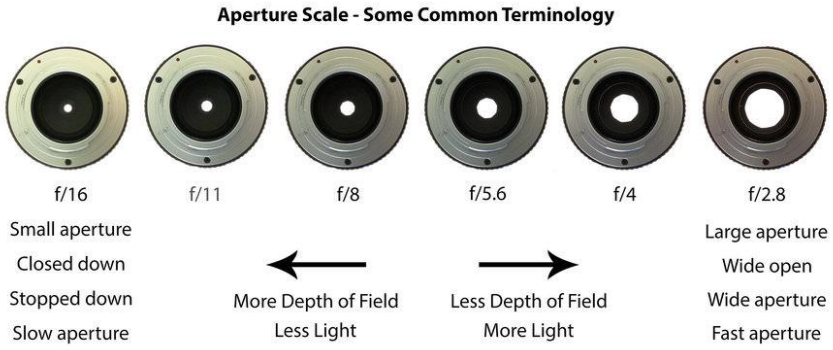
Five-Hundred-Meter Aperture Spherical Radio Telescope (FAST), China

Square Kilometer Array (SKA), South Africa (mid-frequency) / Australia (low-frequency) -artist's impression-

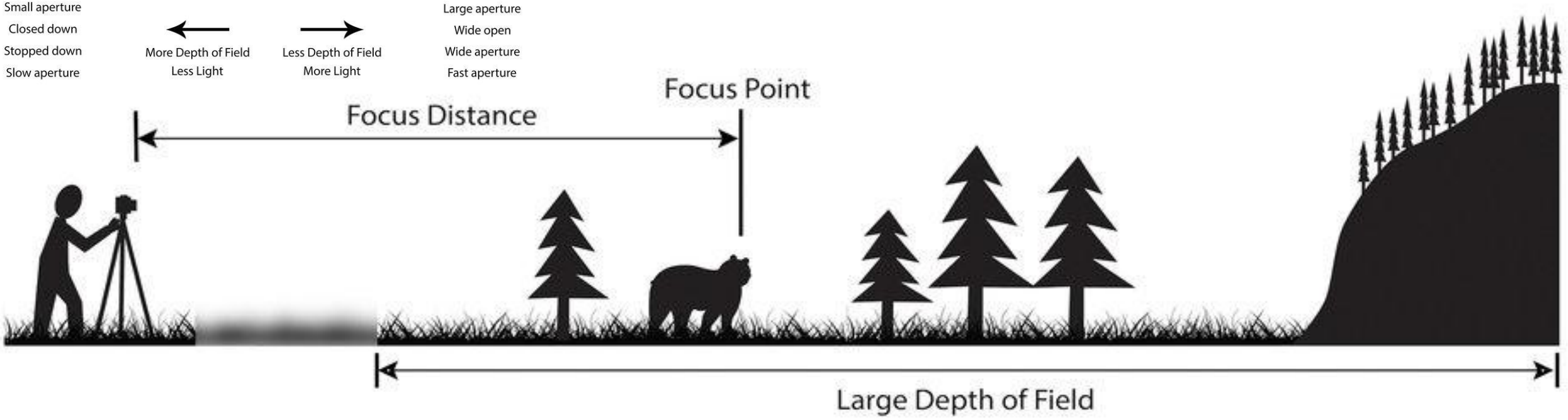


Depth of Field

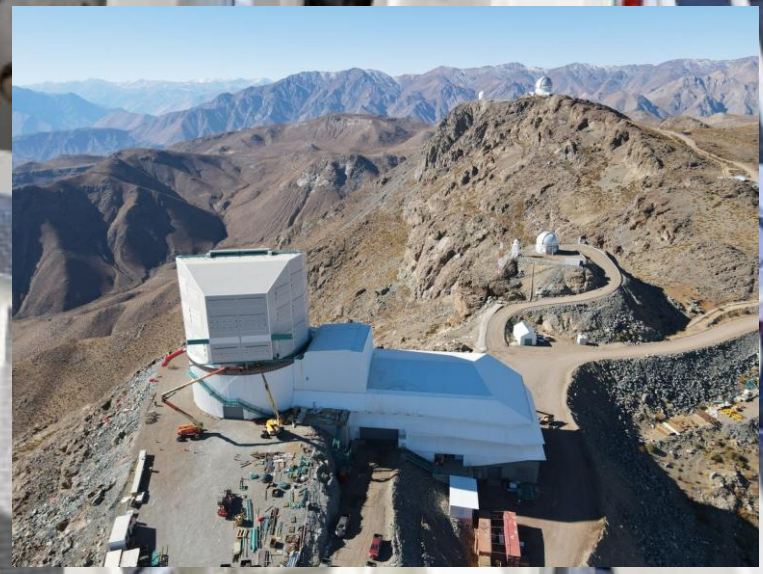




We need an aperture of several (10-100) meters!



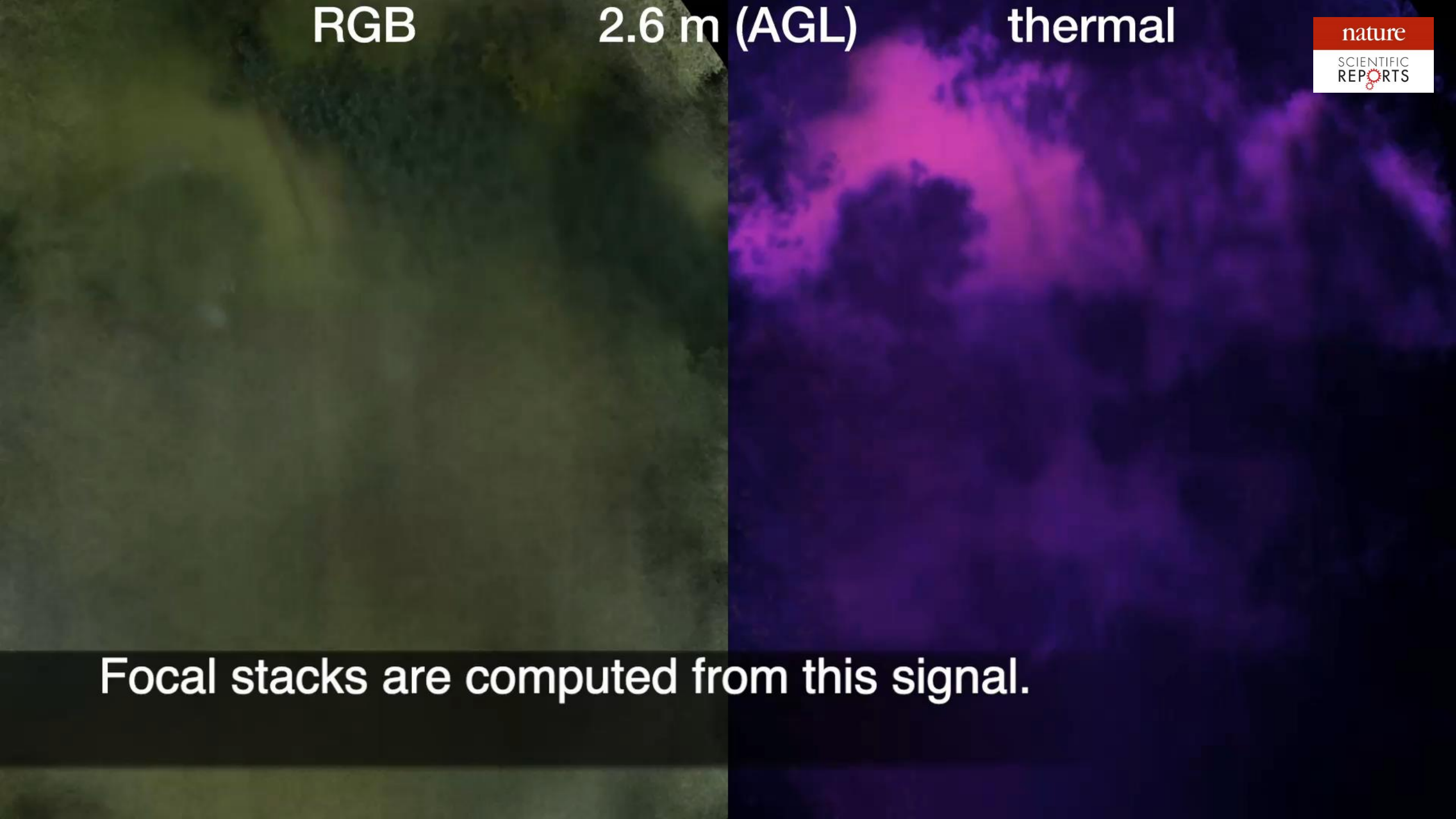
Vera C. Rubin Observatory, Chile

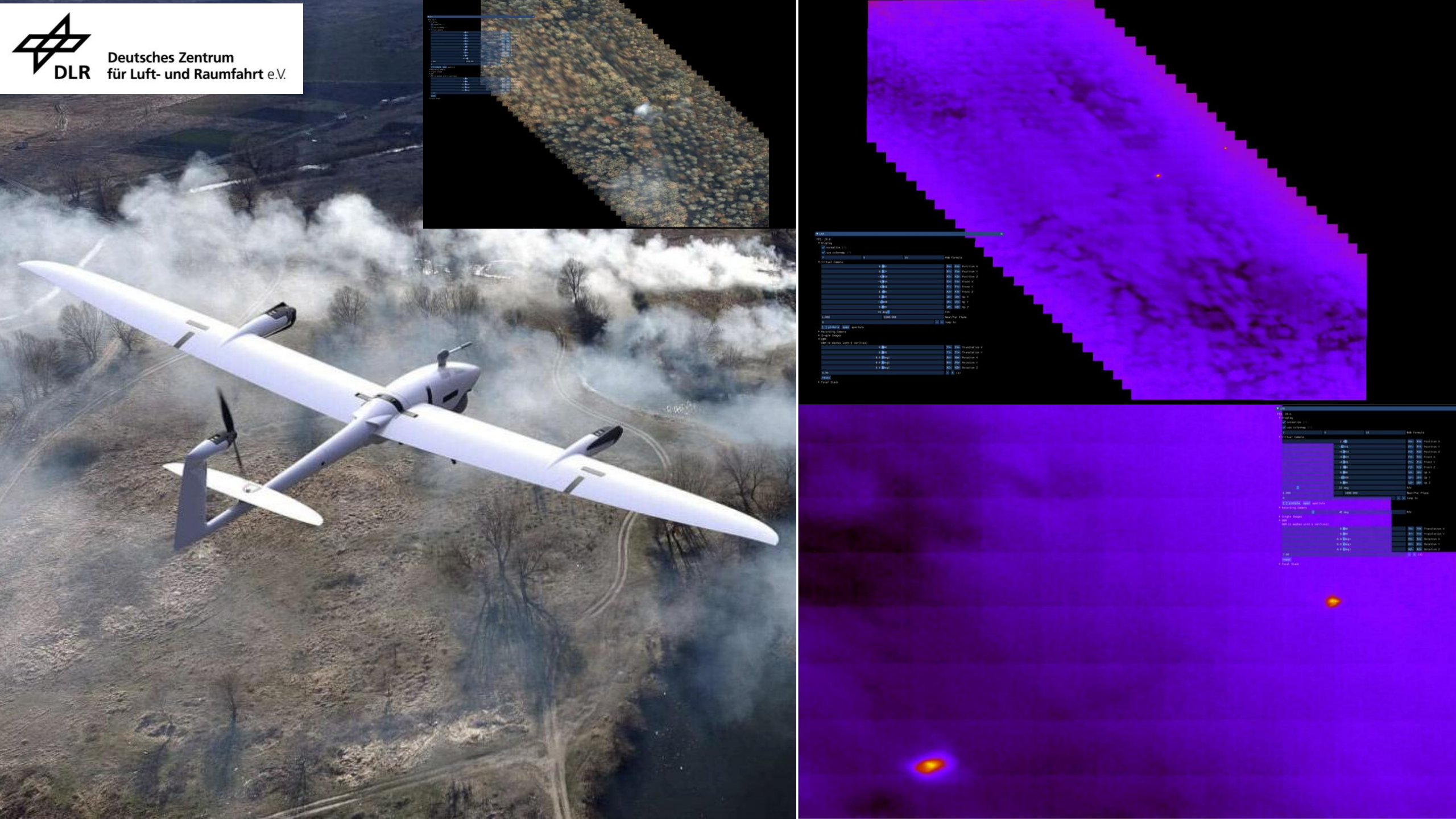



AOS

Airborne Optical Sectioning

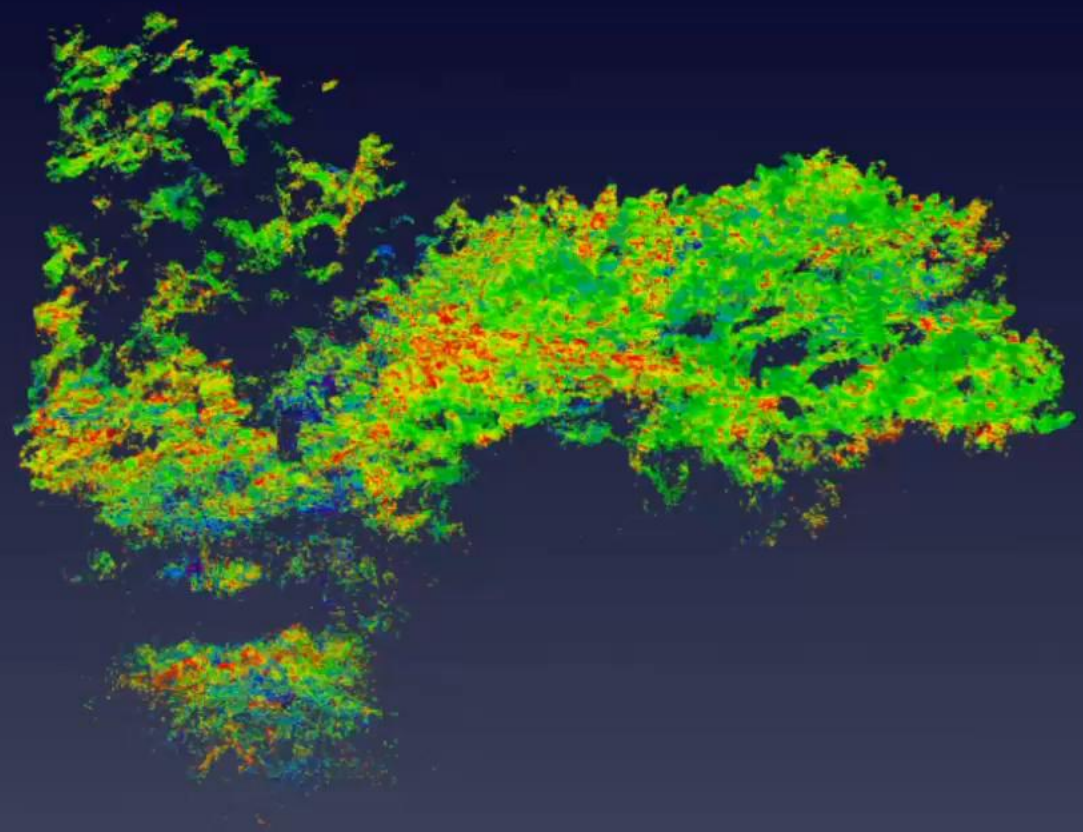
nature machine intelligence
Science Robotics

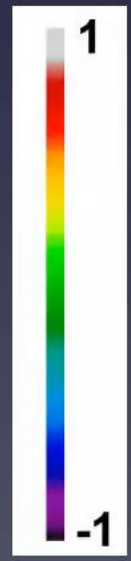

RGB
2.6 m (AGL)
thermal
Focal stacks are computed from this signal.


DLR
Deutsches Zentrum
für Luft- und Raumfahrt e.V.

Journal of Remote Sensing
A SCIENCE PARTNER JOURNAL

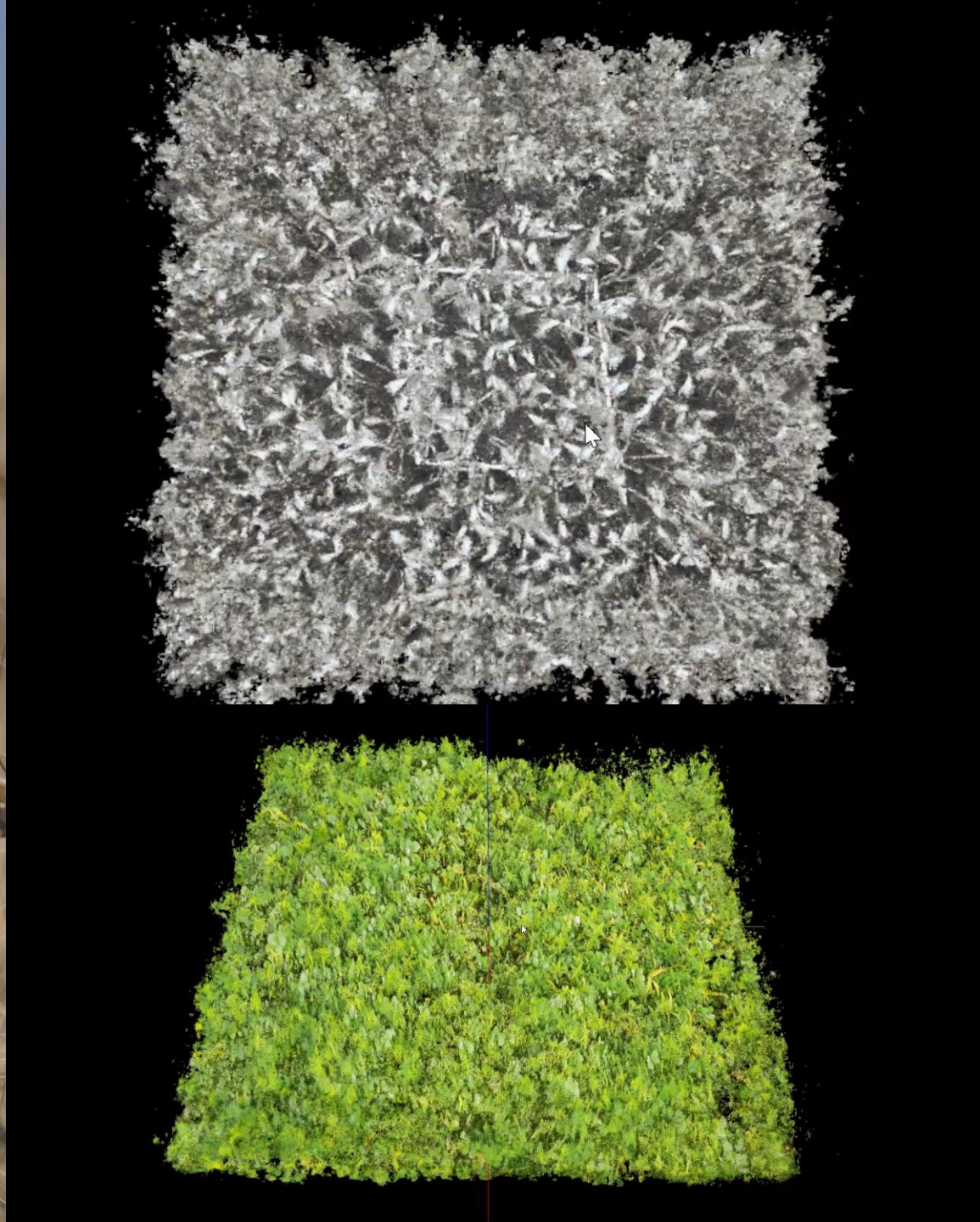
UFZ HELMHOLTZ Zentrum für Umweltforschung





extracted top vegetation layer
(corrected and sensor-mapped)

ÖSTERREICHISCHE HAGELVERSICHERUNG

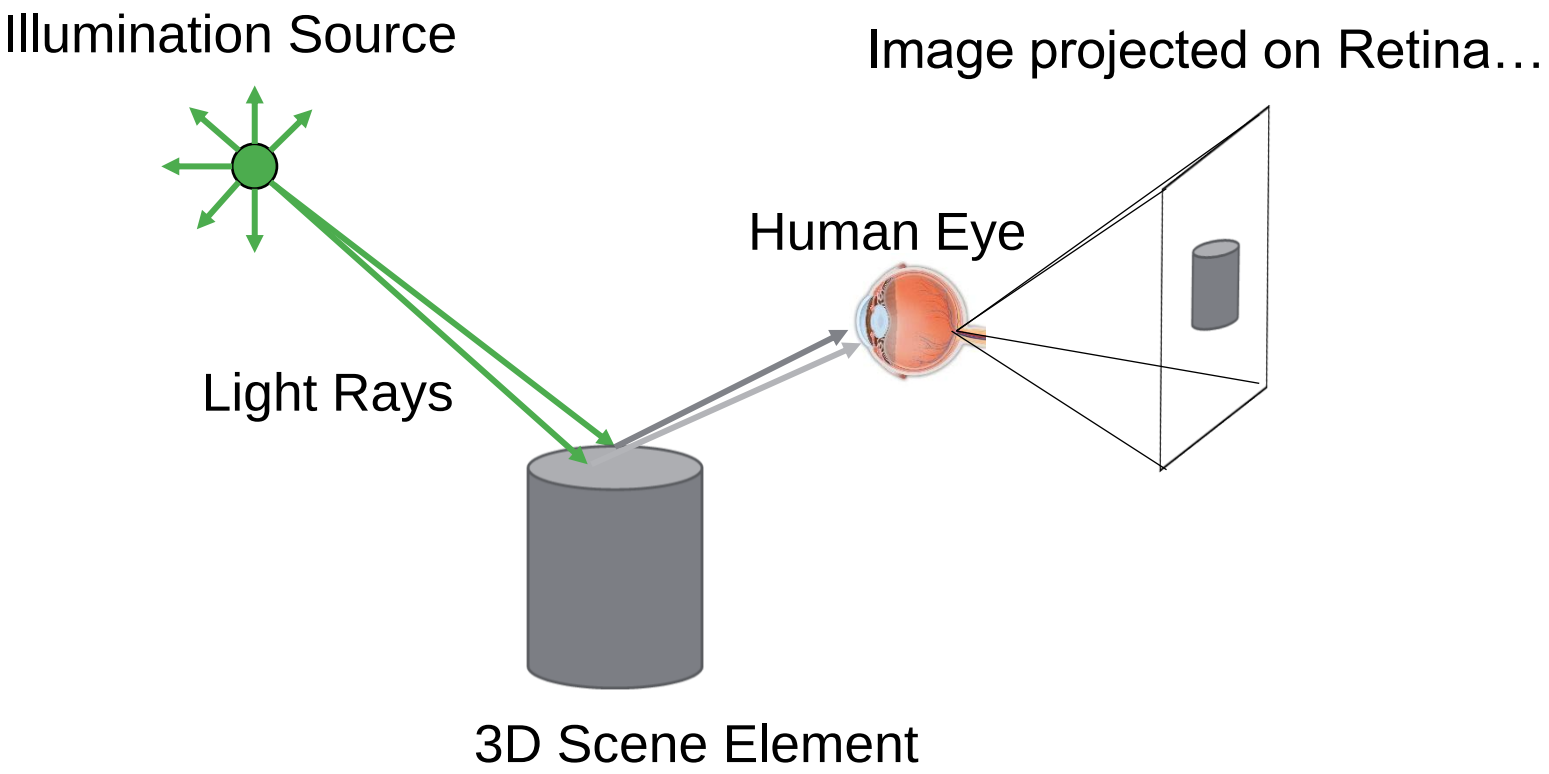


nature communications engineering

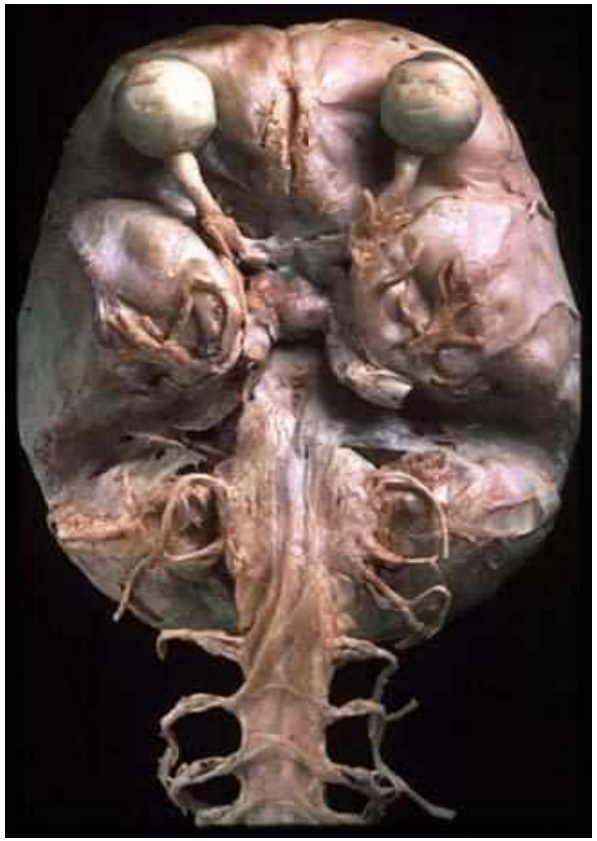
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

Computer Vision – where do we start?

How Humans see the World (in Principle)

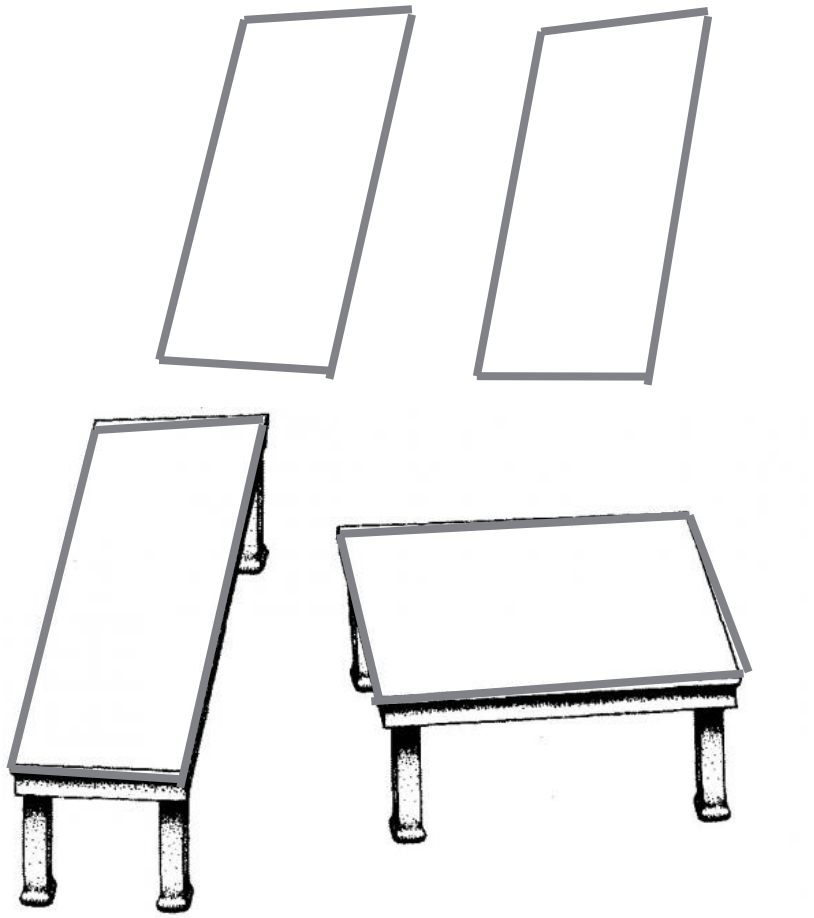


…processed by our Brain

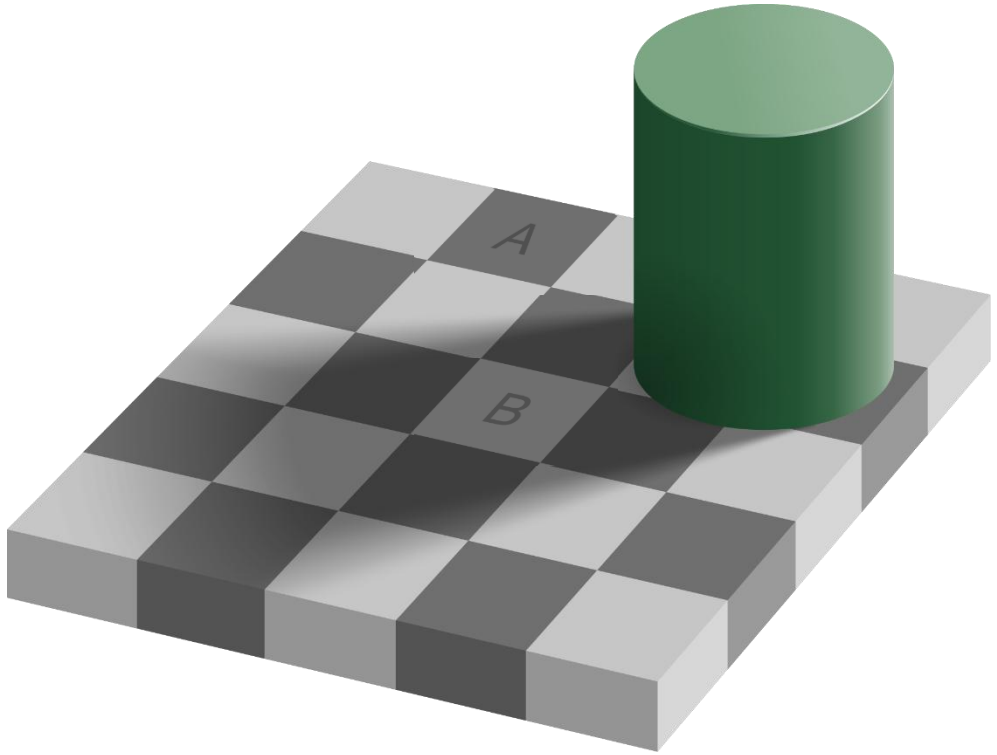


Our Brain is really good at using learned Context

Our Brain is really good at using learned Context

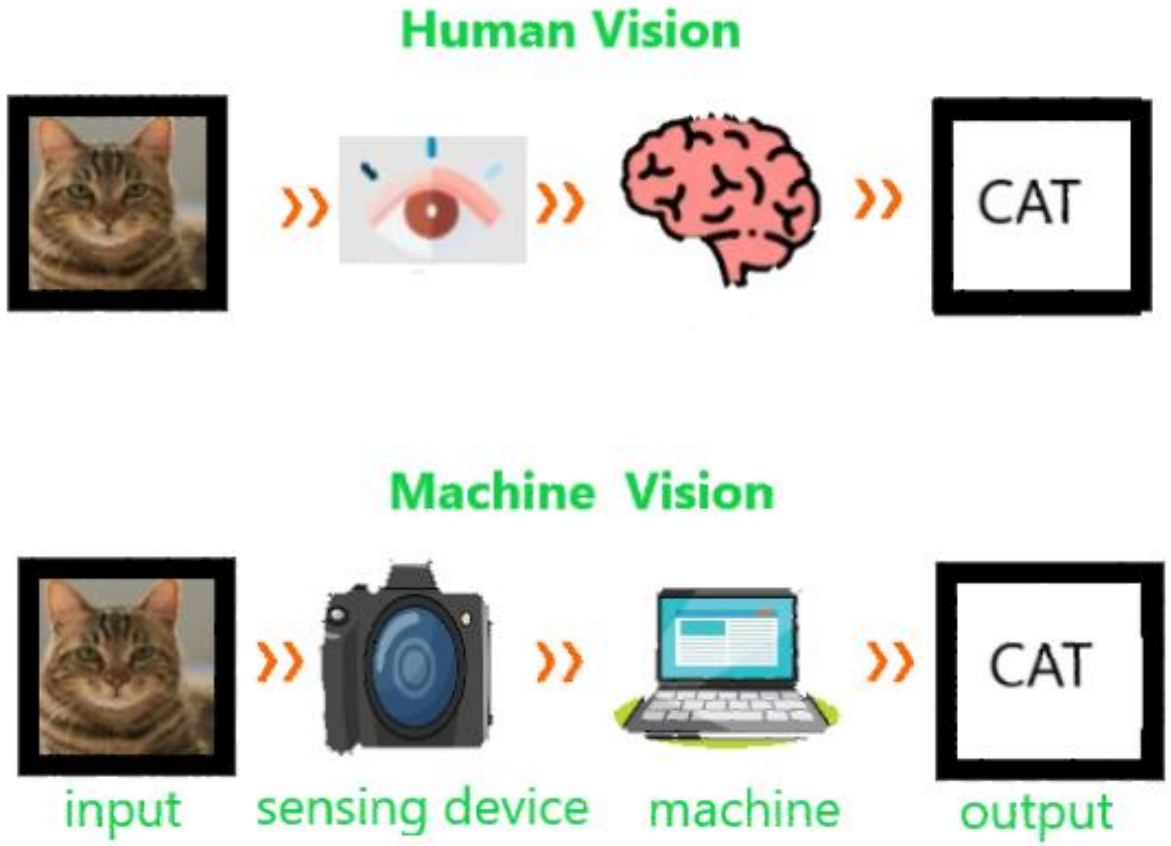


Shepherd Tabletop Illusion



Anderson Shadow Illusion

How Computers see the World (in Principle)

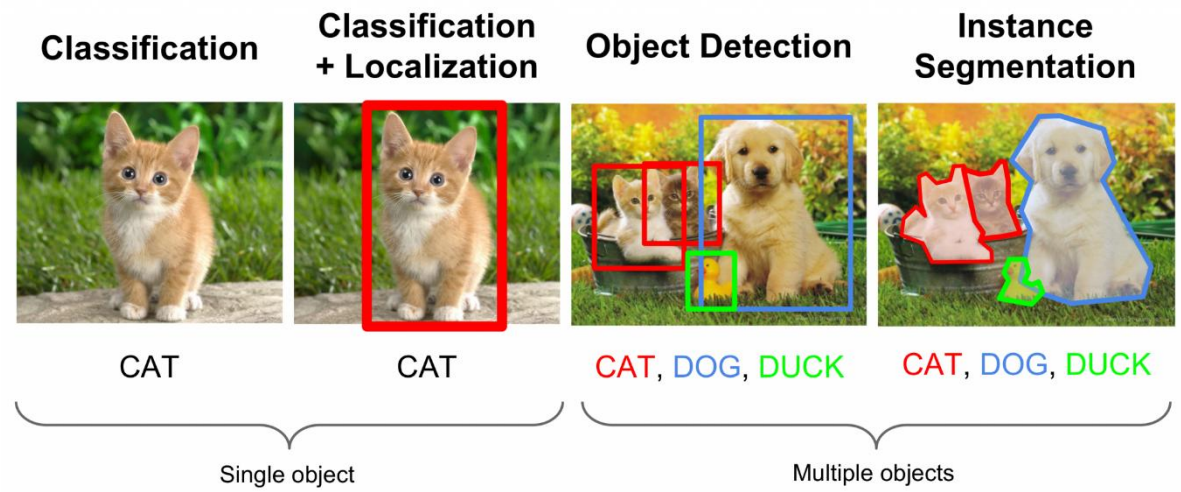


0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

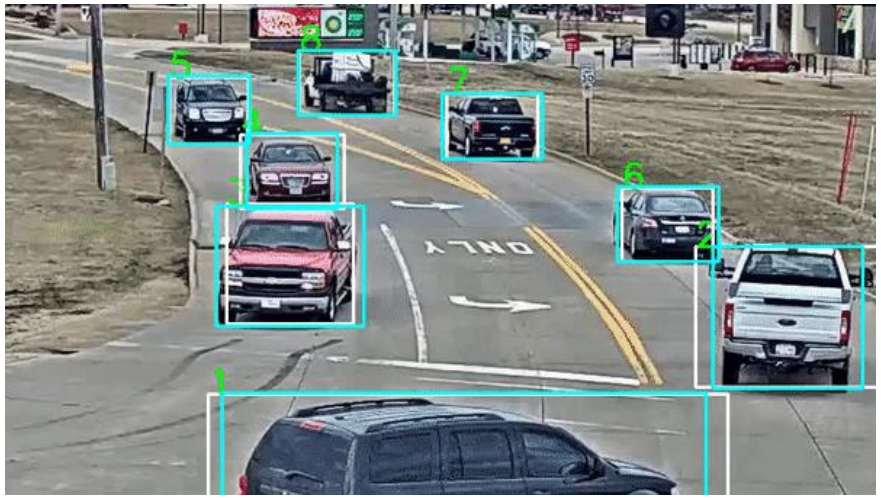
Digital Image

Classical Computer Vision Tasks

Classification



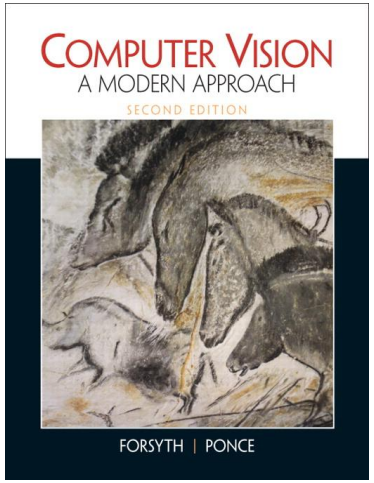
Motion Estimation and Tracking

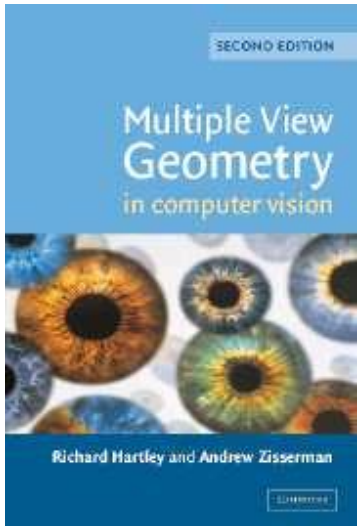


Scene Reconstruction

For Computers, Vision is not that easily (yet)

First Decades of Computer Vision

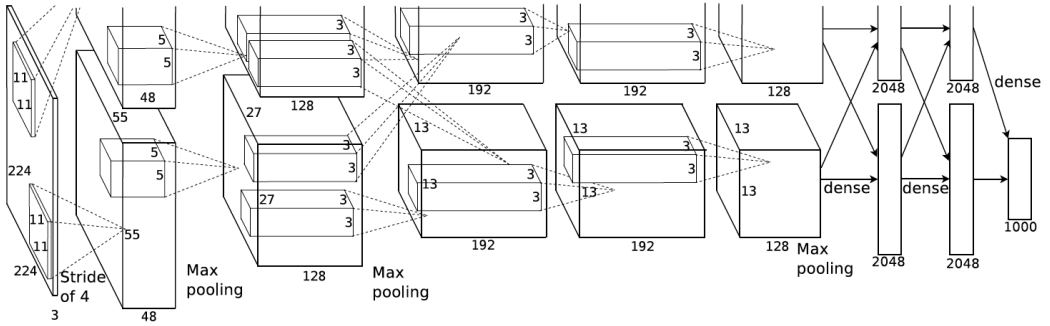




- **1960s and 70s: The "early Years"**
  - Community gets over its Blocks World Phase
  - Canonical recovery Problems are defined and initial Approaches are proposed
  - Ambitious Scene understanding Approaches flower briefly and prematurely
  - Marr's Book sums up Progress to Date
- **1980s and 90s: The "middle ages"**
  - Progress on many Fronts
  - The Field goes through its Geometric Recognition Phase
  - Multi-view Geometry matures and becomes useful, as summarized in the Hartley & Zisserman book
  - The Field stops being afraid of pixels and discovers Data and Classifiers
- **2000s and 2010s: The "early modern era"?**
  - Local Features "solve" Structure from Motion and Instance Recognition
  - Generic Category Recognition and Detection become central Problems
  - The Field becomes driven by Datasets and Benchmarks

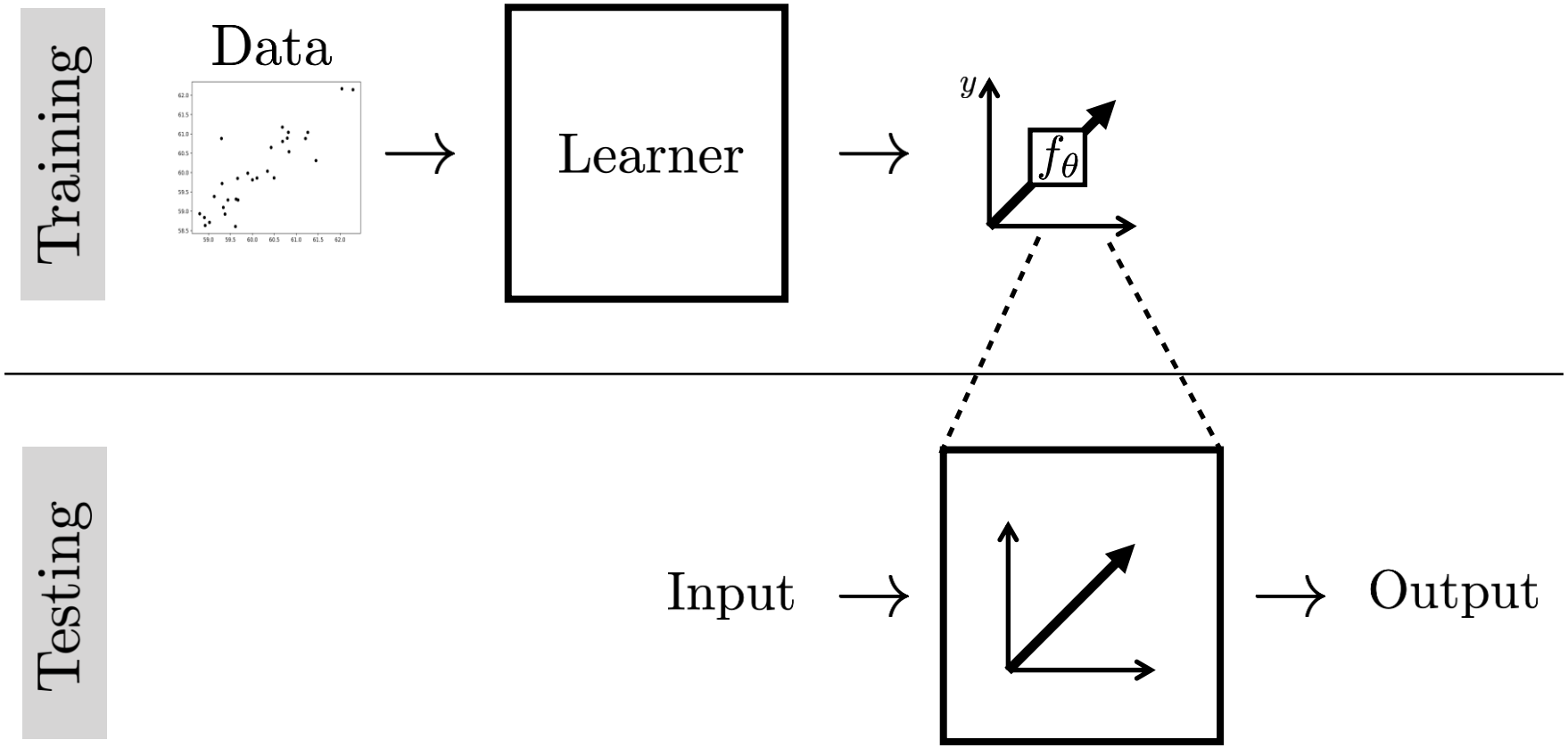
Where are we now?

Machine Learning= Data-driven Intelligence



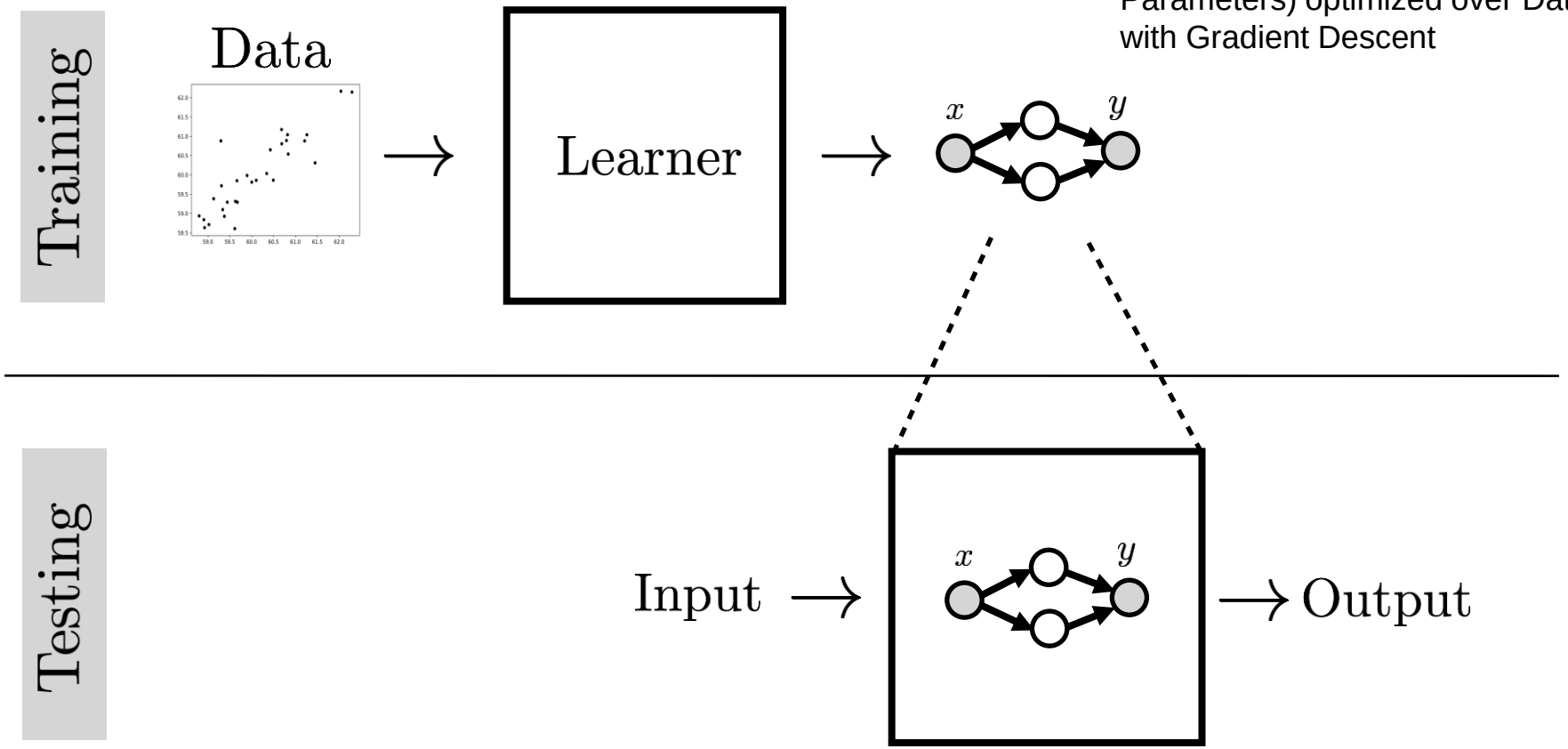
2012: AlexNet

Learning from Data

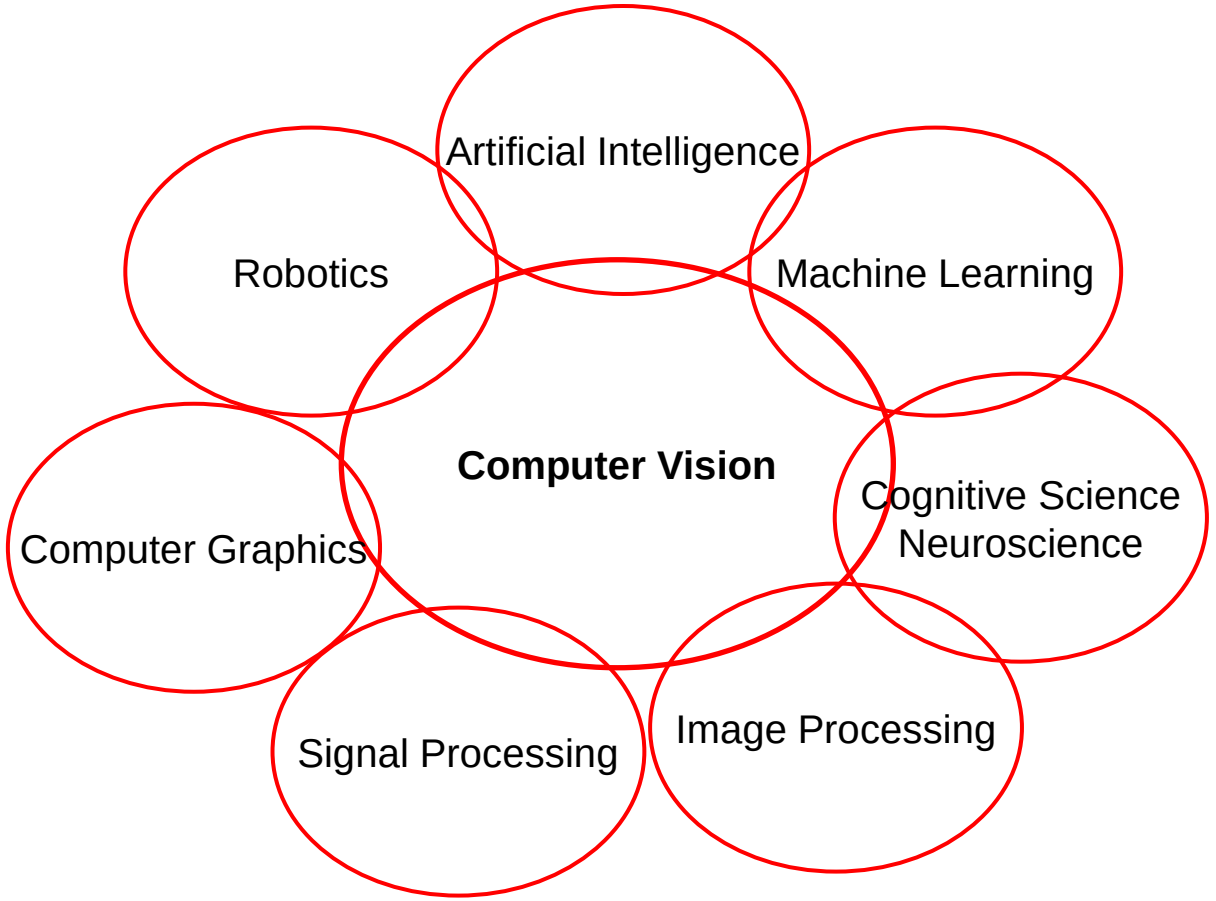


Learning from Data

Deep Neural Networks: Models (typically with millions of Parameters) optimized over Data with Gradient Descent

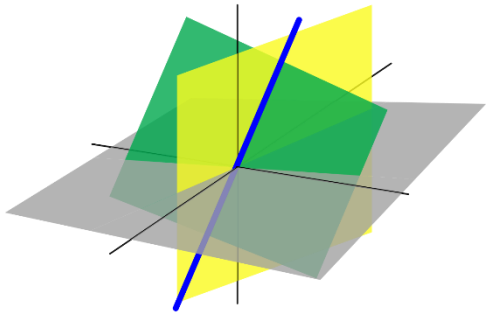


Related Fields



Required Basic Knowledge

Python



Linear Algebra

Machine Learning

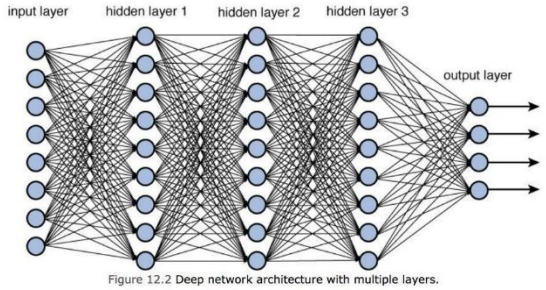
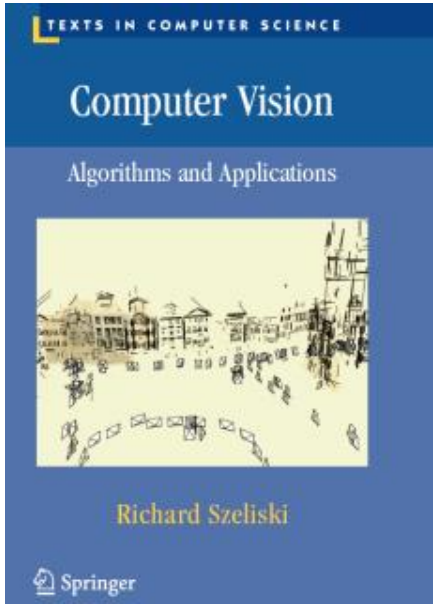
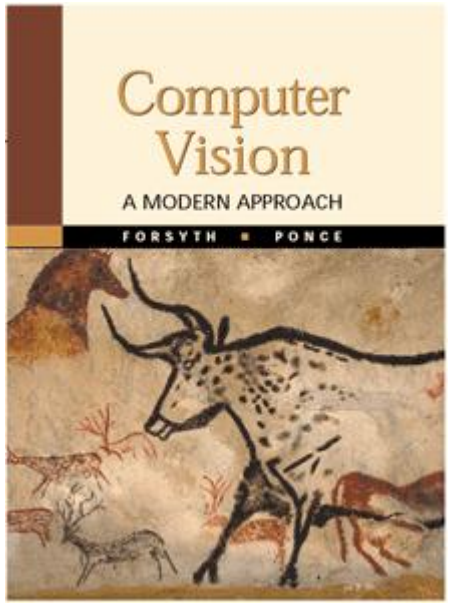


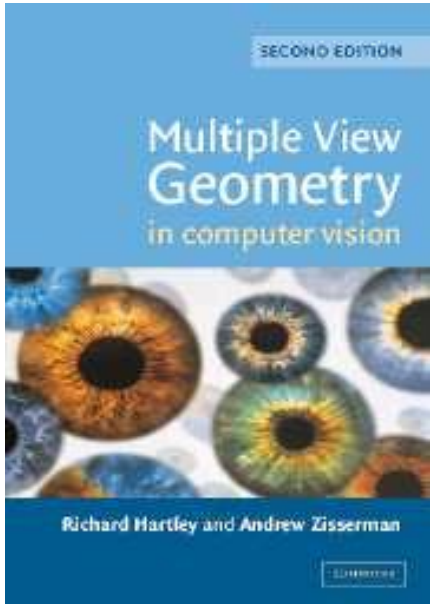
Figure 12.2 Deep network architecture with multiple layers.

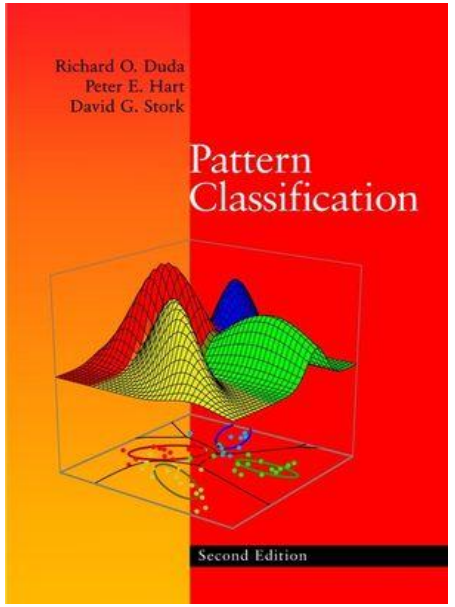
Neural Networks

Recommended Text Books









free download (Link in Moodle)

Material in Slides is partially compiled from multiple Sources: Lecture Material of other Universities (TU Munich, RICE University, MIT, Stanford University); Supplementary Material of Text Books (Computer Vision: Algorithms and Applications, Computer Vision: A Modern Approach); various Internet Sources.

Course Organization

- **Lectures (3 ETCS)**
  - 12 Lecture Appointments
  - Zoom only
  - Live: Tuesdays, 12:00-13:30
  - Recordings and Slides available (Moodle)
- **Labs and Assignments (1.5 ETCS)**
  - Basic Python and Machine Learning Skills required
  - 2 Onboarding Labs (Zoom only)
  - 4 Assignments (related to Lecture Topics)
  - 4 Open Labs (Zoom only / Hybrid)
  - All Labs and Open Labs Repeated at various Days / Times per Week
  - Recordings, Code, Model-Solutions, Slides available (Moodle)
- **Grading**
  - Lecture: Moodle Exam / Retry-Exam (100%)
  - Lab: Each Assignment 25% (4x = 100%)
- **Attendance**
  - No Attendance required in Lectures (but recommended, questions will be addressed in Lectures)
  - Physical Presence required for Exams
  - Onboarding Labs recommended to refresh required Programming Skills
  - Open Labs recommended for addressing Problems and Questions

Oliver Bimber
Full Professor
Head of the Department

Computer Science Building, room 302
Phone: +43 (732) 2468-6630
oliver.bimber(/\t)jku.at

Mohammed Abbass
Senior Lecturer

Computer Science Building, room 359
Phone: +43 (732) 2468-6636
mohammed.abbass(/\t)jku.at

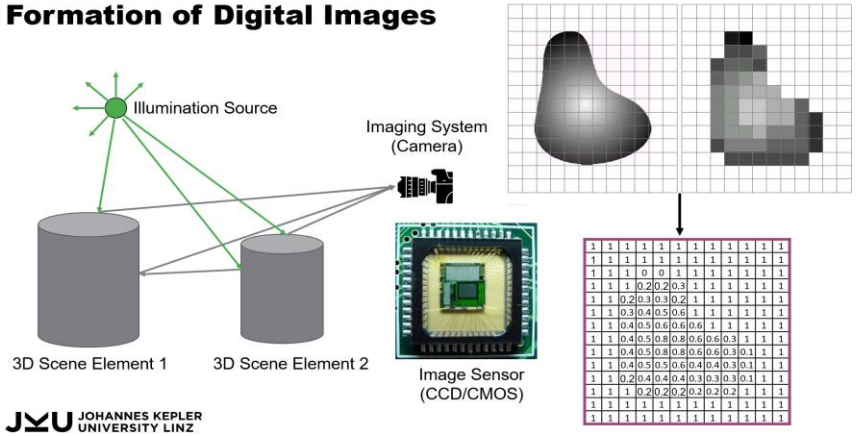
+ tutors

Course Overview

CW	Topic	Date	Place	Lab
41	Introduction and Course Overview	07.10.2025	Zoom	Lab 1
42	Capturing Digital Images	14.10.2025	Zoom	Lab 2
43	Digital Image Processing	21.10.2025	Zoom	Assignment 1
44	Machine Learning	28.10.2025	Zoom	
45	Feature Extraction	04.11.2025	Zoom	Open Lab 1
46	Segmentation	11.11.2025	Zoom	Assignment 2
47	Optical Flow	18.11.2025	Zoom	Open Lab 2
48	Object Detection	25.11.2025	Zoom	Assignment 3
49	Multi-View Geometry	02.12.2025	Zoom	Open Lab 3
50	3D Vision	09.12.2025	Zoom	Assignment 4
3	Trends in Computer Vision	13.01.2026	Zoom	
4	Q&A	20.01.2026	Zoom	Open Lab 4
5	Exam	27.01.2026	HS1 (Linz), S1/S3 (Vienna), S5 (Bregenz)	
9	Retry Exam	24.02.2026	tba	

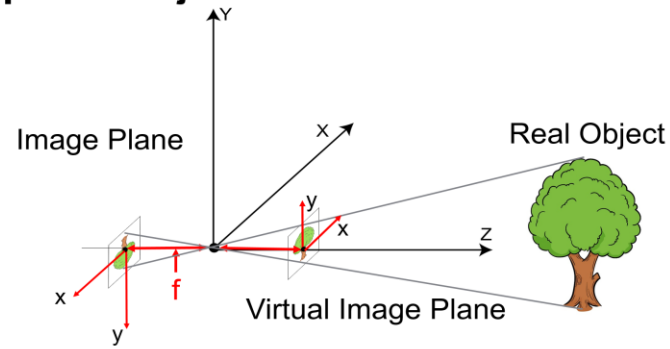
Next Week: Capturing Digital Images

Formation of Digital Images



JOHANNES KEPLER UNIVERSITY LINZ

Perspective Projection



JOHANNES KEPLER UNIVERSITY LINZ

On a lower Level: Detect Features (e.g., Edges)

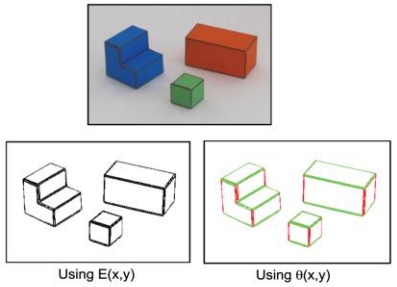


Image gradient:

$$\nabla \mathbf{I} = \left(\frac{\partial \mathbf{I}}{\partial x}, \frac{\partial \mathbf{I}}{\partial y} \right)$$

Approximation image derivative:

$$\frac{\partial \mathbf{I}}{\partial x} \simeq \mathbf{I}(x,y) - \mathbf{I}(x-1,y)$$

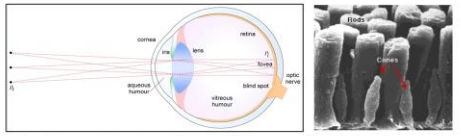
Edge strength $E(x,y) = |\nabla \mathbf{I}(x,y)|$

Edge orientation: $\theta(x,y) = \angle \nabla \mathbf{I} = \arctan \frac{\partial \mathbf{I}/\partial y}{\partial \mathbf{I}/\partial x}$

Edge normal: $\mathbf{n} = \frac{\nabla \mathbf{I}}{|\nabla \mathbf{I}|}$

JOHANNES KEPLER UNIVERSITY LINZ

How Humans do it?



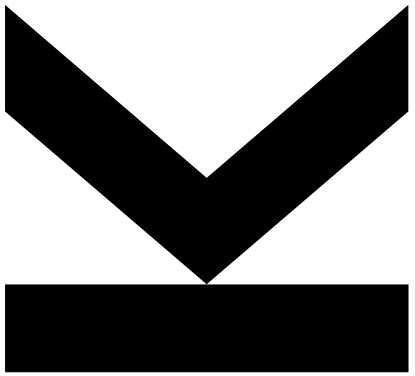
The Human Eye is a biological Camera (Lens, Aperture=Iris, Sensor=Retina) and is used for Measurement=Sensing.

The Perception of the Visual Cortex is really what we want to mimic with Computer Vision!

JOHANNES KEPLER UNIVERSITY LINZ

JOHANNES KEPLER UNIVERSITY LINZ

Thank You



JOHANNES KEPLER
UNIVERSITY LINZ