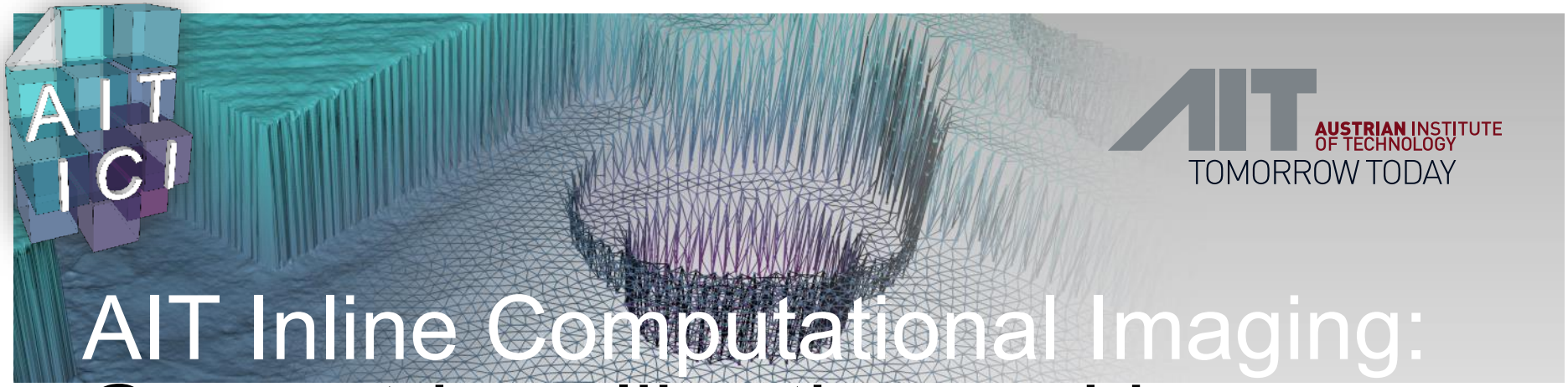
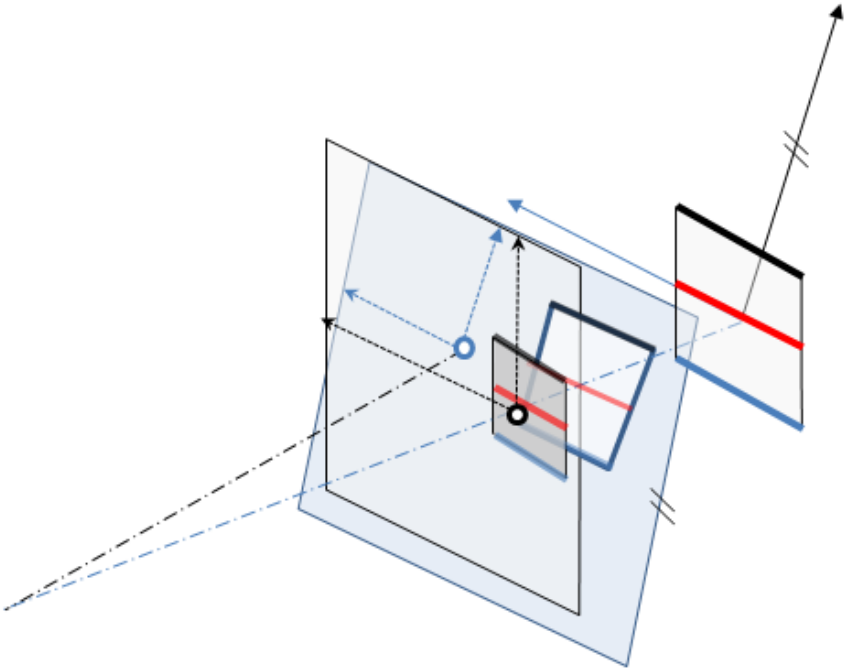


AIT Inline Computational Imaging: Geometric calibration and image rectification

B. Blaschitz, S. Štolc and S. Breuss

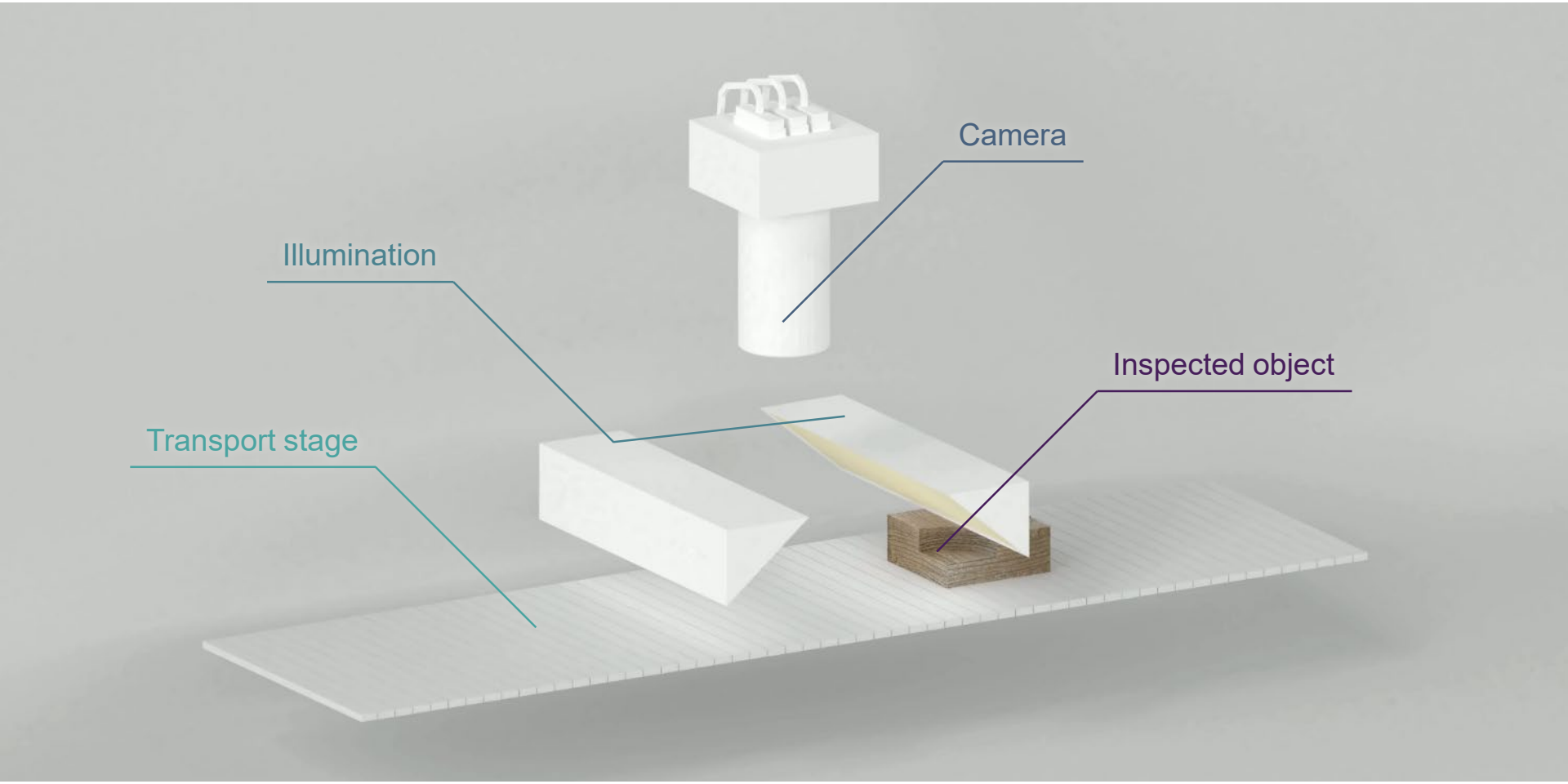
AIT Austrian Institute of Technology GmbH
Center for Vision, Automation & Control
Vienna, Austria

www.ait.ac.at/hpv



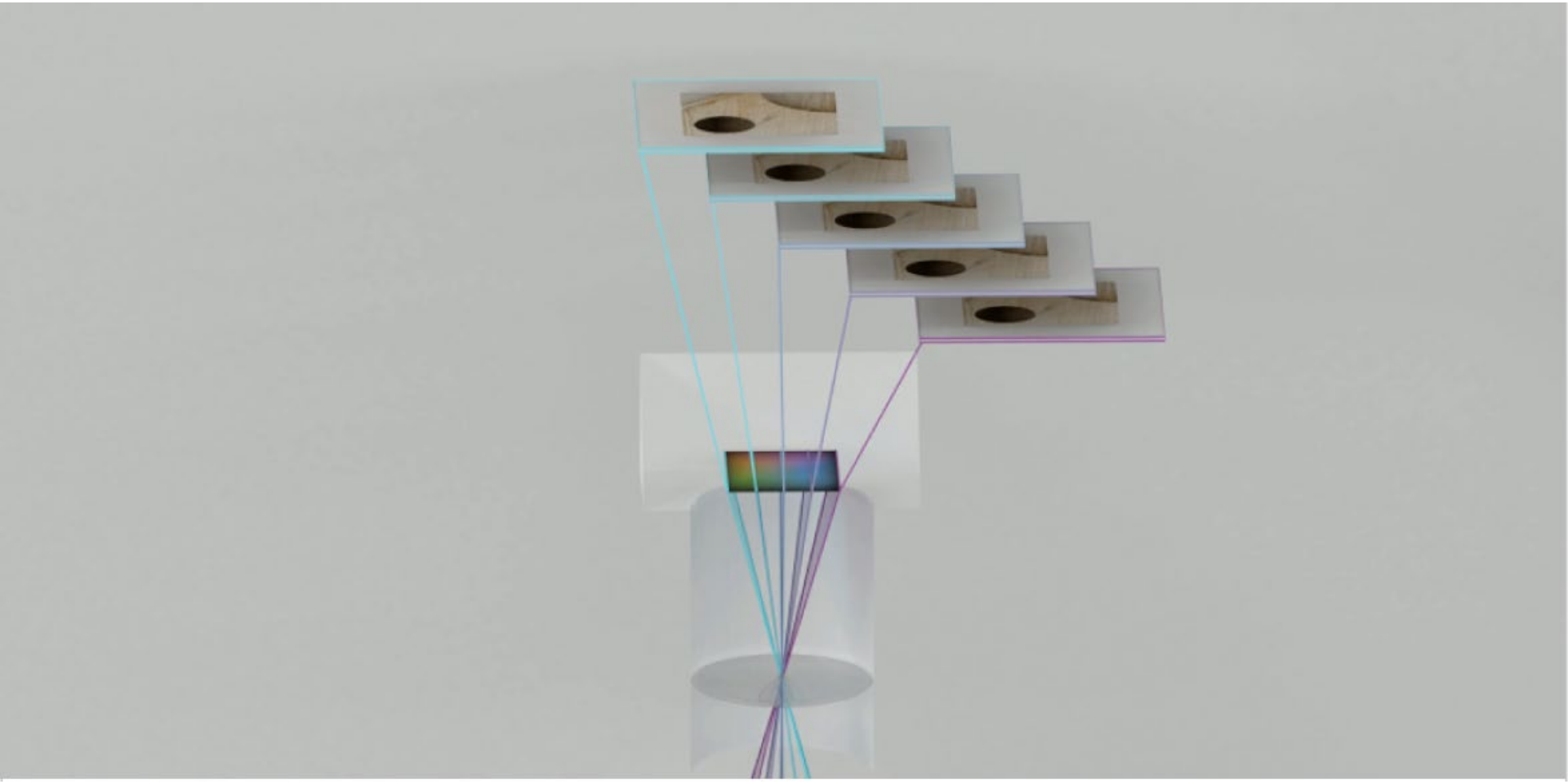
AUSTRIAN INSTITUTE OF TECHNOLOGY

INLINE COMPUTATIONAL IMAGING: WORKING PRINCIPLE

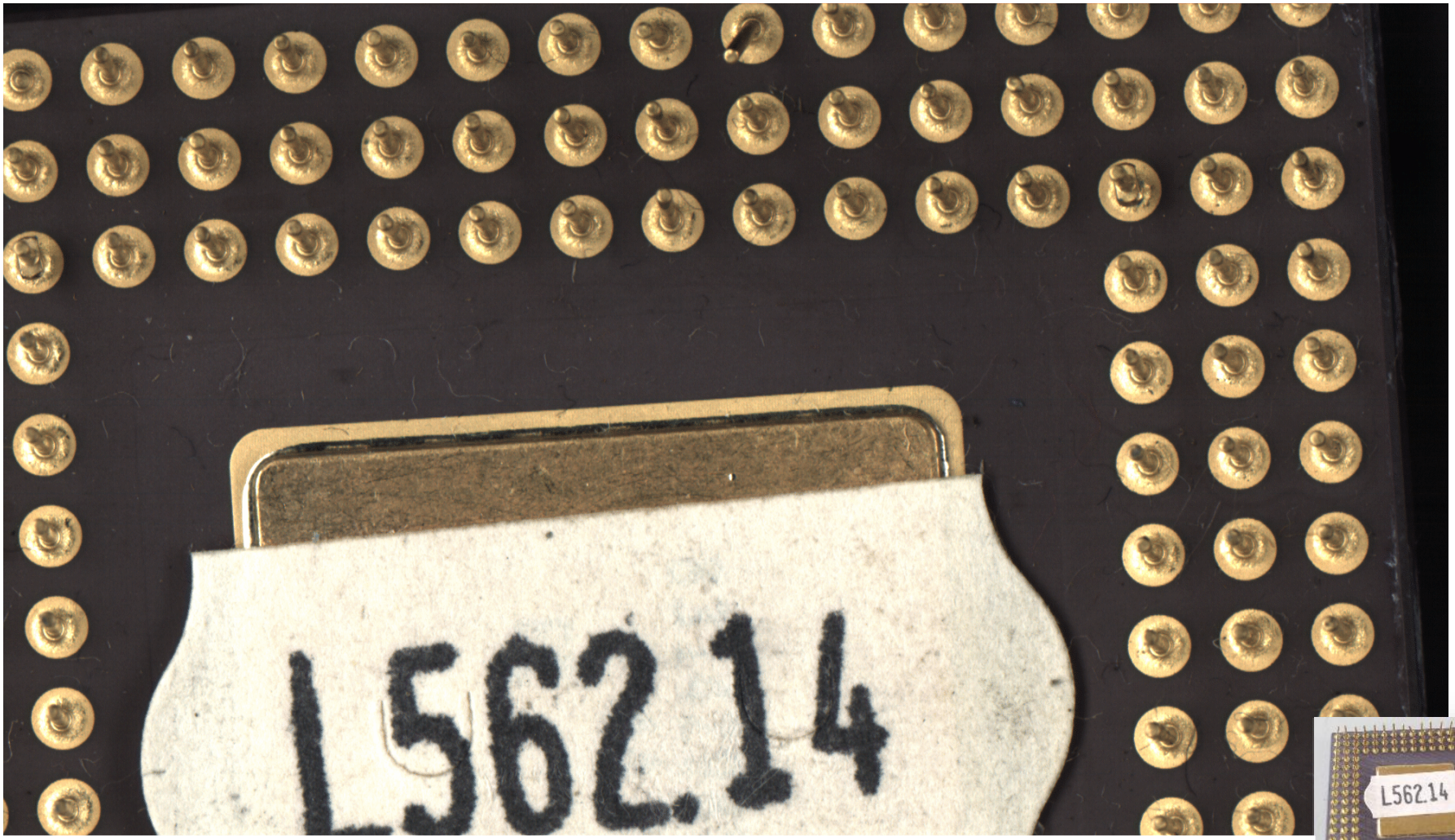


AUSTRIAN INSTITUTE OF TECHNOLOGY

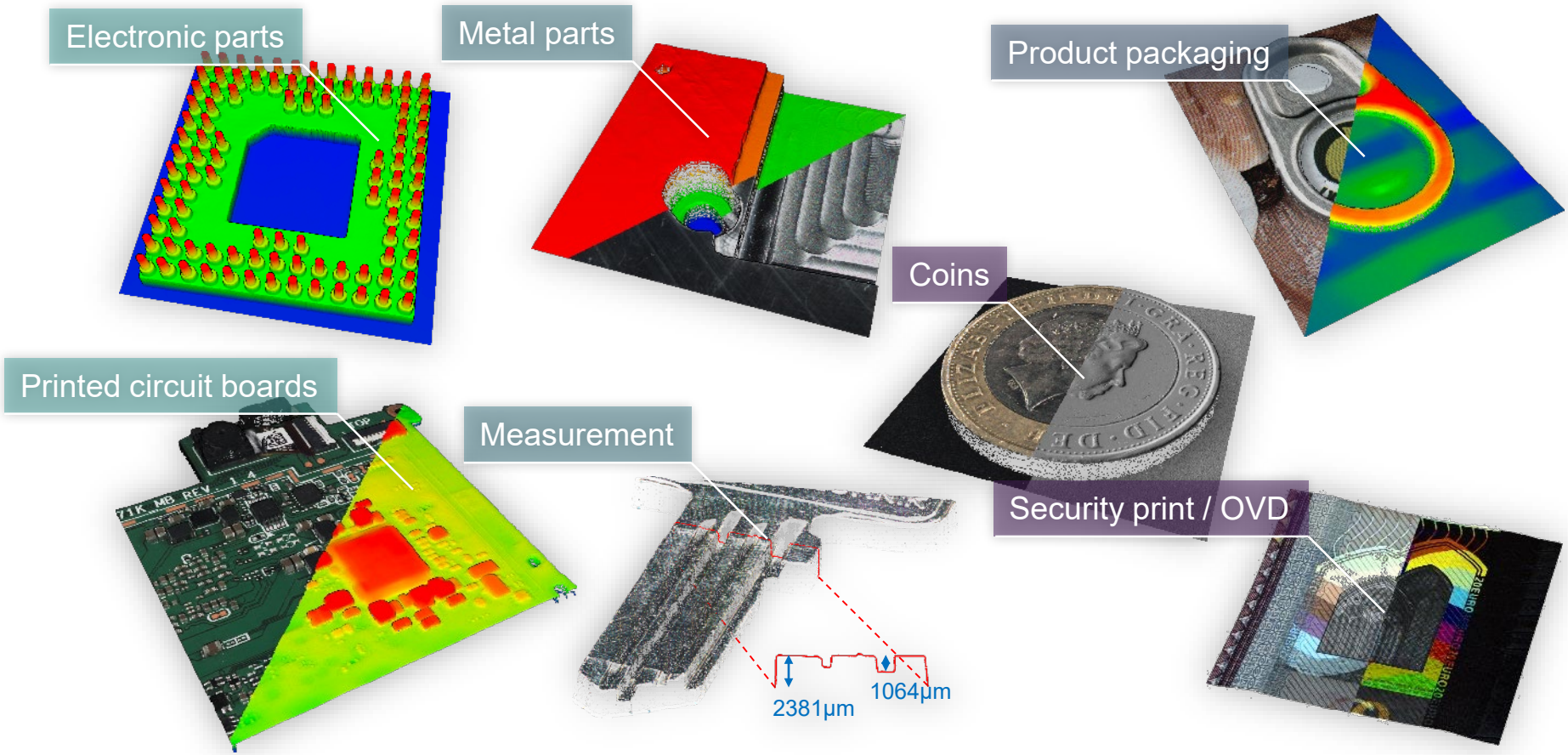
INLINE COMPUTATIONAL IMAGING: WORKING PRINCIPLE



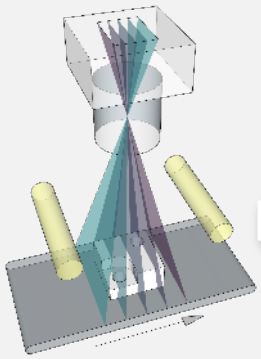
AIT ICI **LIGHT FIELD:** MULTIPLE VIEWING & ILLUMINATION ANGLES



AIT INLINE COMPUTATIONAL IMAGING: INDUSTRIAL USE CASES



ICI SOFTWARE MODULES FOR 2D/3D TASKS



ICI Sensor System
- Camera
- Illumination
- Transport stage

Acquisition
- Light field data acquisition
- Camera, illumination, and transport control

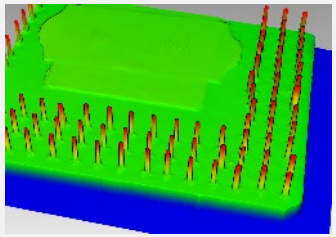
Rectification
- Camera lens undistortion & rectification
- Transport misalignment correction

Feature extraction
- Extraction of robust image features
- Extraction of local surface features

Stereo matching
- High speed multi-view / light field stereo matching

Coarse refinement
- Fast discrete depth denoising / regularization preserving discontinuities

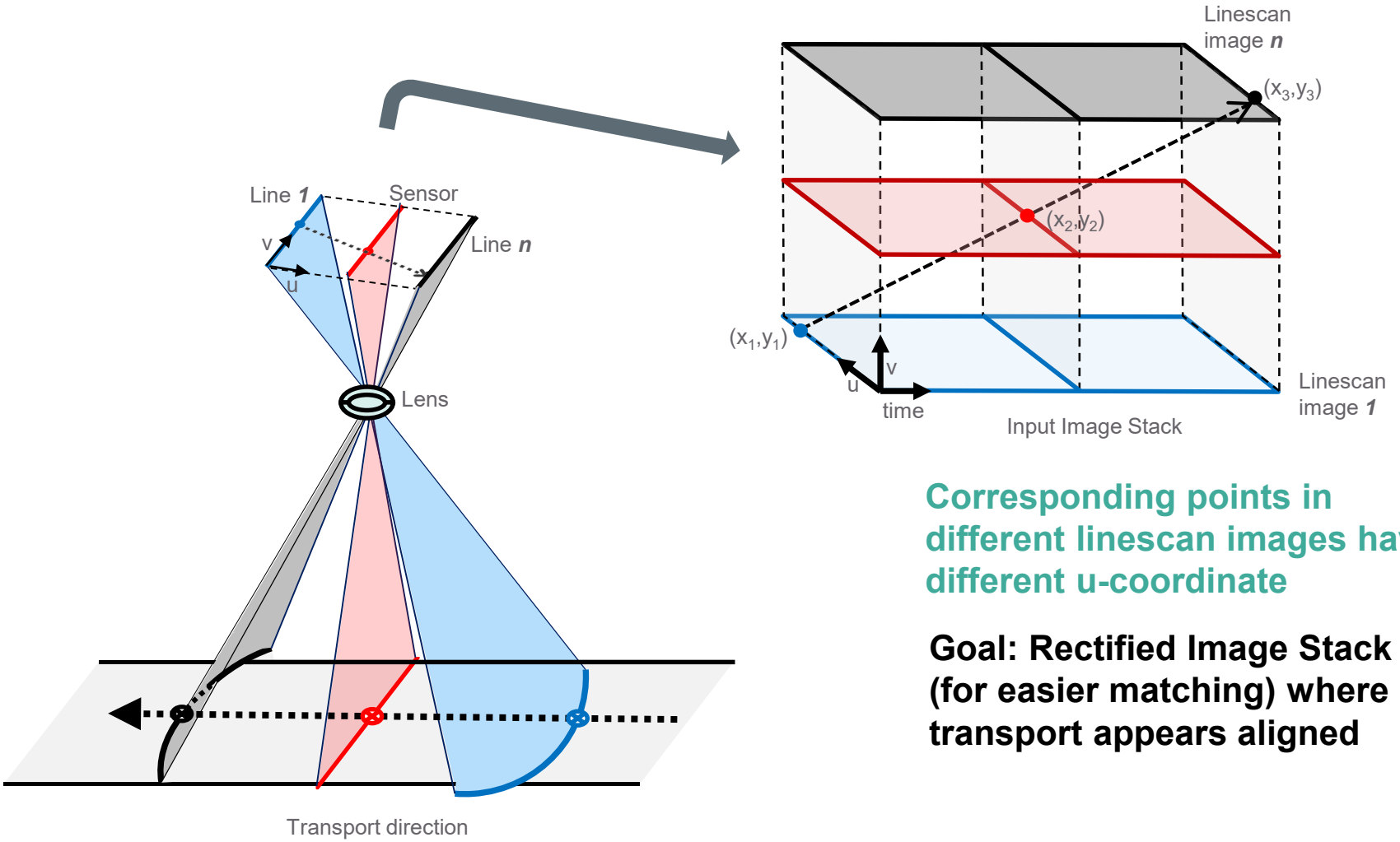
Fine refinement
- Fast continuous depth / regularization
- Fusion with additional depth cues



Refined 2D/3D data
- Fine depth model (depth map, point cloud)
- Depth measurement confidence
- Refined 2D texture images (all-in-focus, gloss / shadow suppression)
- Fine 2.5D surface map

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

MODELLING SKEW TRANSPORT

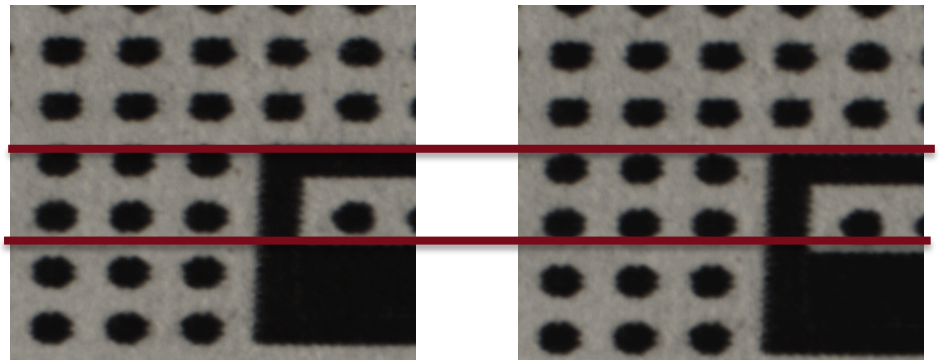


Corresponding points in different linescan images have different u-coordinate

Goal: Rectified Image Stack (for easier matching) where transport appears aligned

GOAL: RECTIFIED IMAGE STACK (FOR EASIER MATCHING) WHERE TRANSPORT APPEARS ALIGNED

Corresponding points in different linescan images should have same u-coordinate



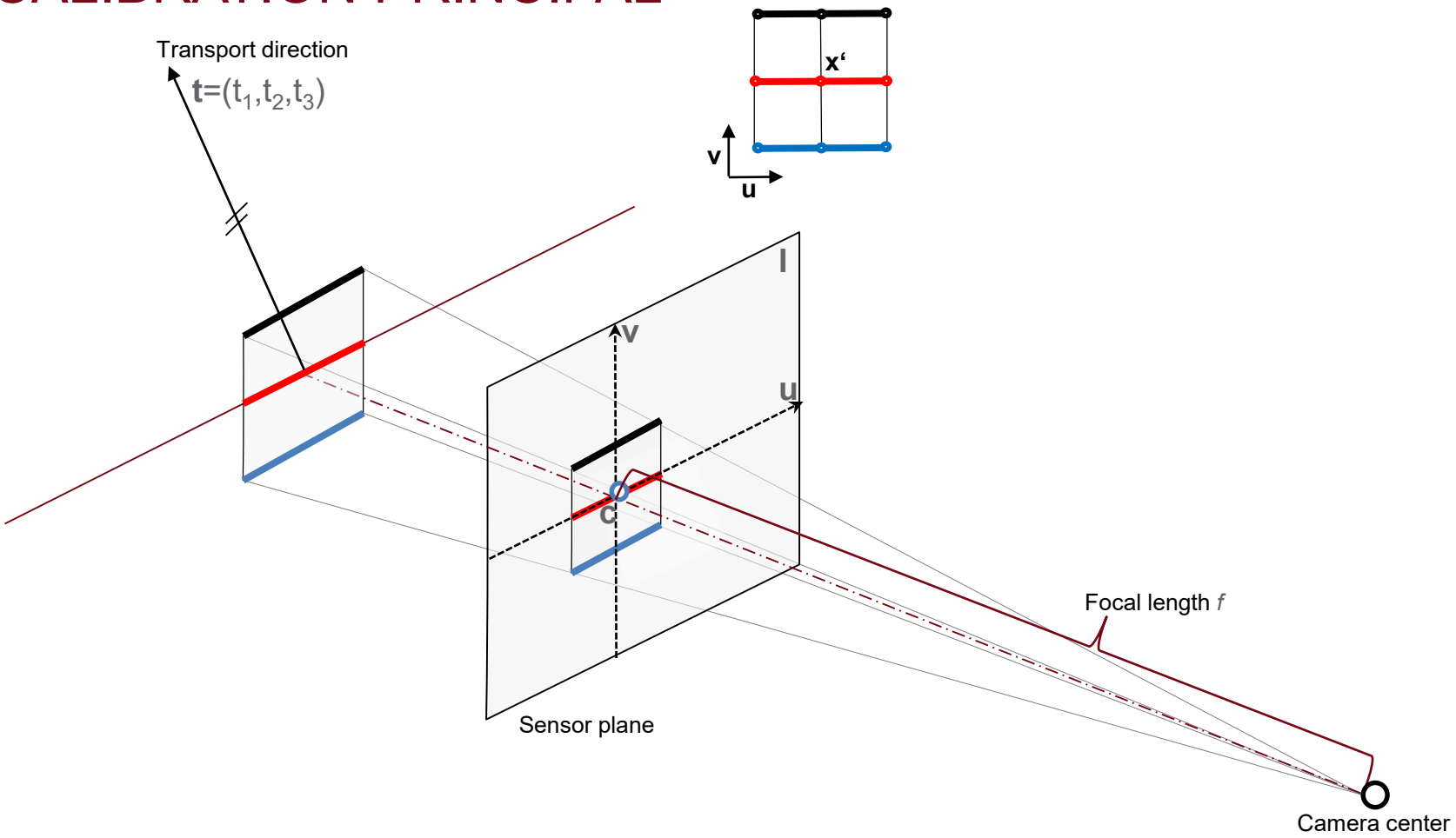
uncalibrated calibrated

Rectification

- Camera lens undistortion & rectification
- Transport misalignment correction

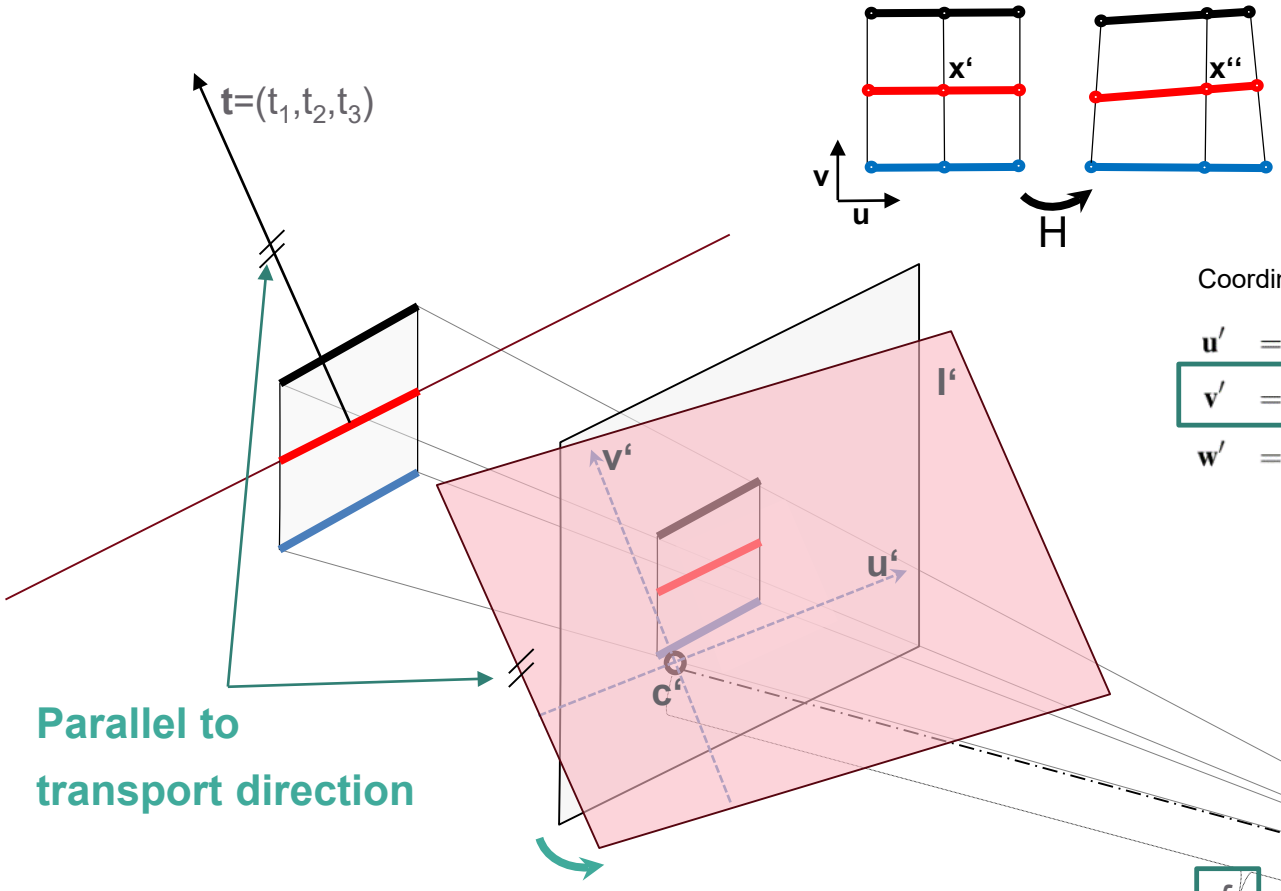
AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

CALIBRATION PRINCIPAL



AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

VIRTUAL IMAGE PLANE I‘



Coordinate system of new image plane I’

$$\mathbf{u}' = 1/\sqrt{t_1^2+t_2^2}\cdot(t_2,-t_1,0)$$

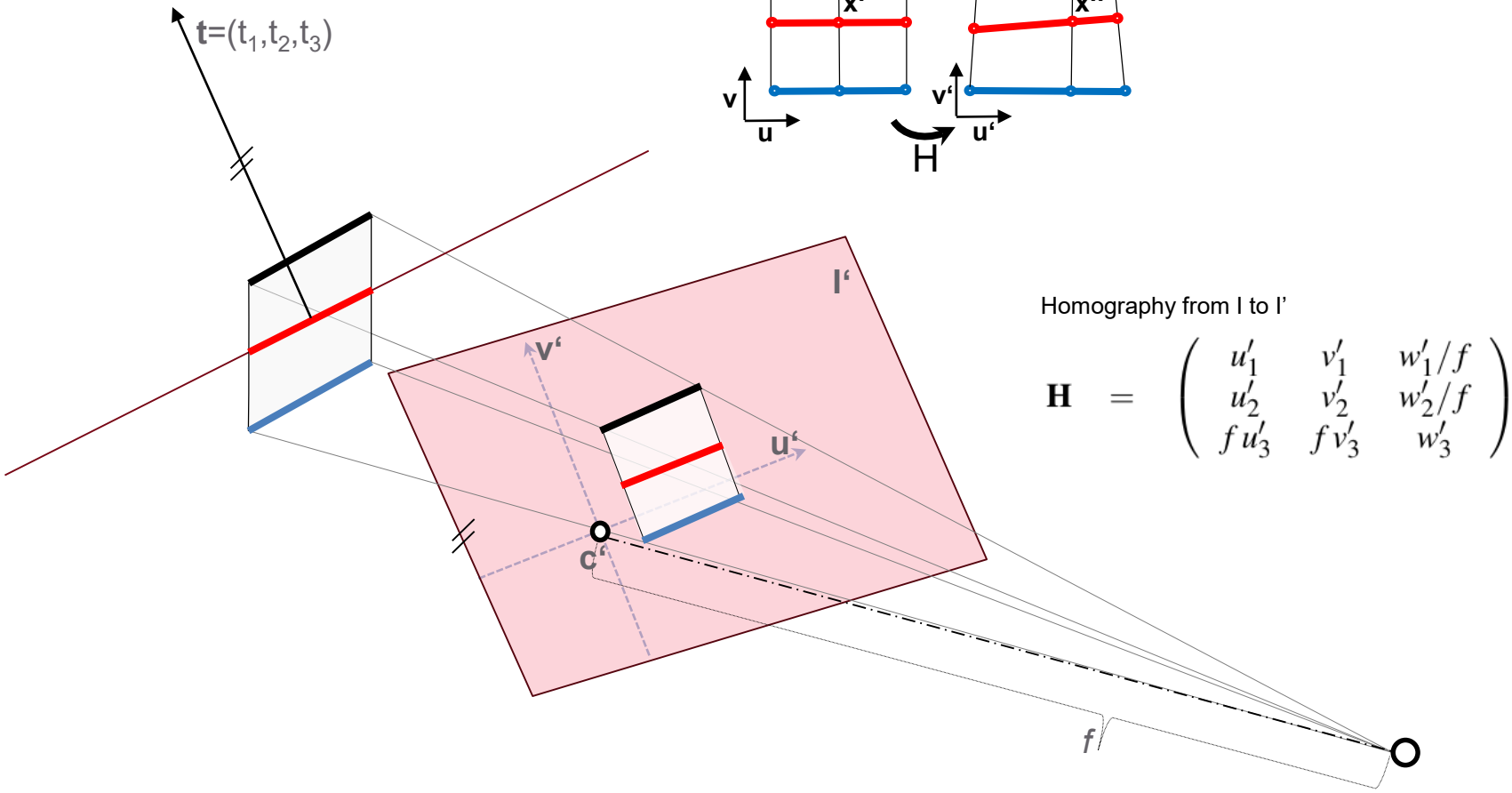
$$\mathbf{v}' = (t_1,t_2,t_3)$$

$$\mathbf{w}' = 1/\sqrt{t_1^2+t_2^2}\cdot(-t_1t_3,-t_2t_3,t_1^2+t_2^2),$$

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

VIRTUAL IMAGE PLANE

Project sensor lines



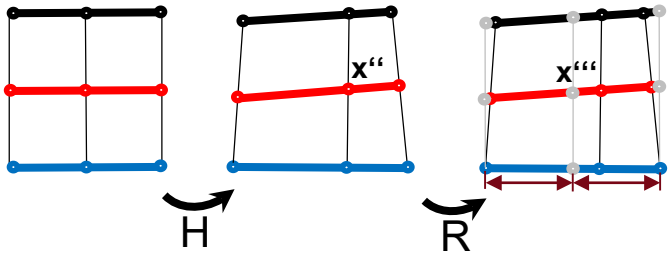
Homography from I to I’

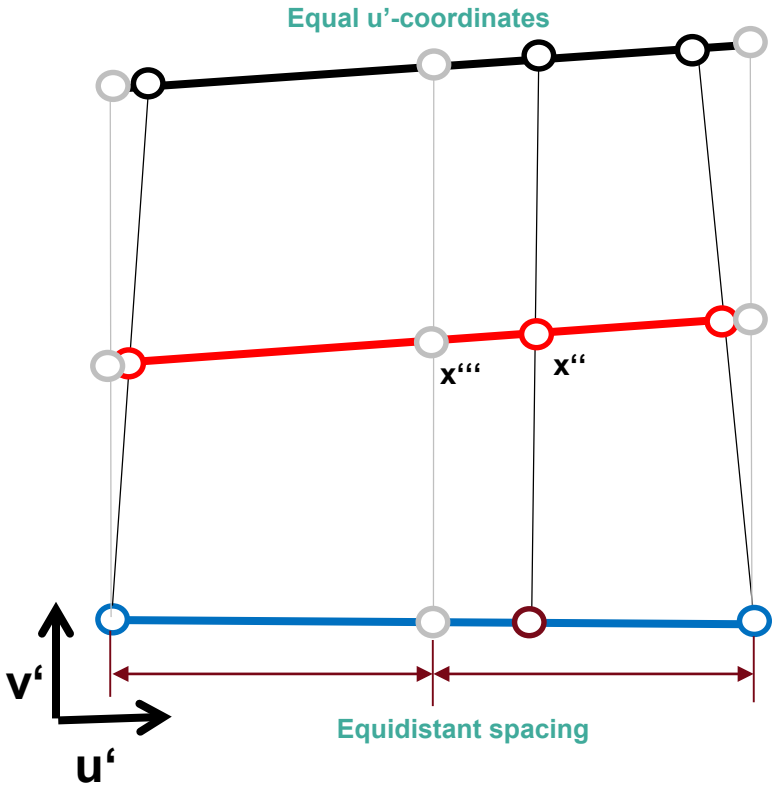
$$\mathbf{H} = \begin{pmatrix} u'_1 & v'_1 & w'_1/f \\ u'_2 & v'_2 & w'_2/f \\ f\,u'_3 & f\,v'_3 & w'_3 \end{pmatrix}$$

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

VIRTUAL IMAGE PLANE

Resample in I'

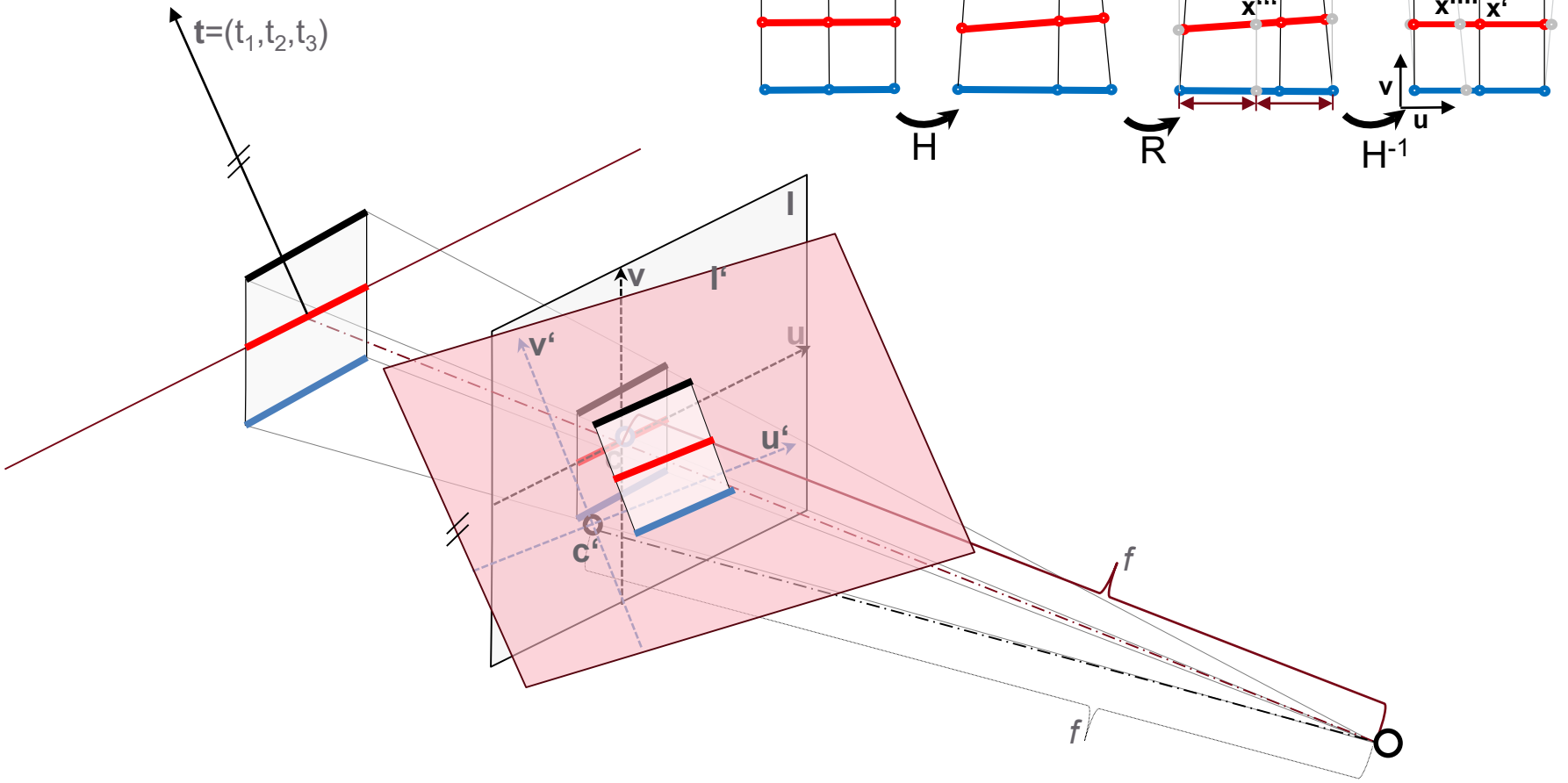




AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

VIRTUAL IMAGE PLANE

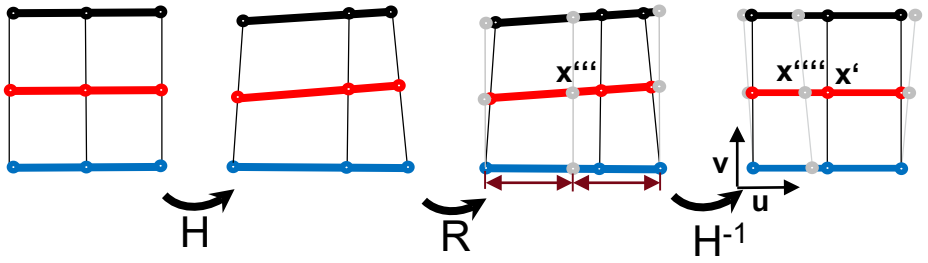
Pull back to I

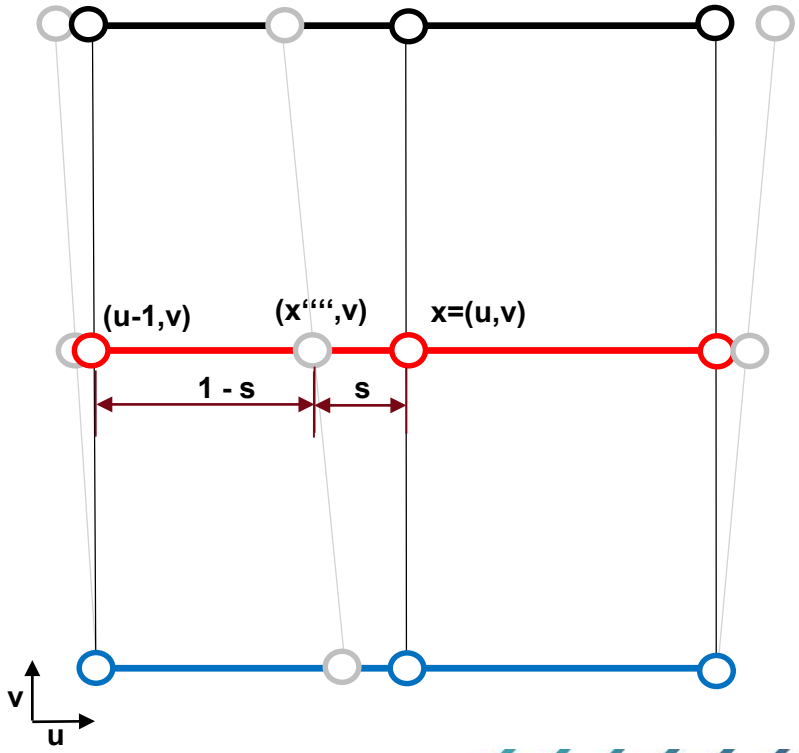


AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

VIRTUAL IMAGE PLANE

Interpolate color values

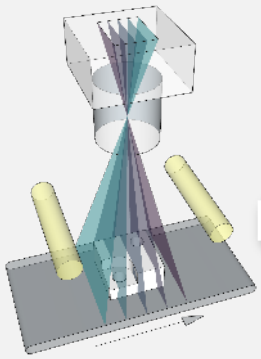




M(u,v) is the color value at position (u,v)

$$M(x'''',v) = s \cdot M(u,v) + (1-s) \cdot M(u-1,v)$$

CALIBRATION IMPROVES STEREO MATCHING



ICI Sensor System
- Camera
- Illumination
- Transport stage

Acquisition
- Light field data acquisition
- Camera, illumination, and transport control

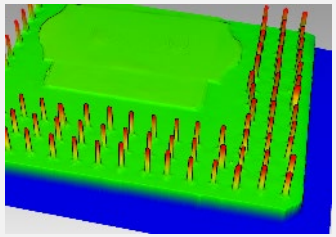
Rectification
- Camera lens undistortion & rectification
- Transport misalignment correction

Feature extraction
- Extraction of robust image features
- Extraction of local surface features

Stereo matching
- High speed multi-view / light field stereo matching

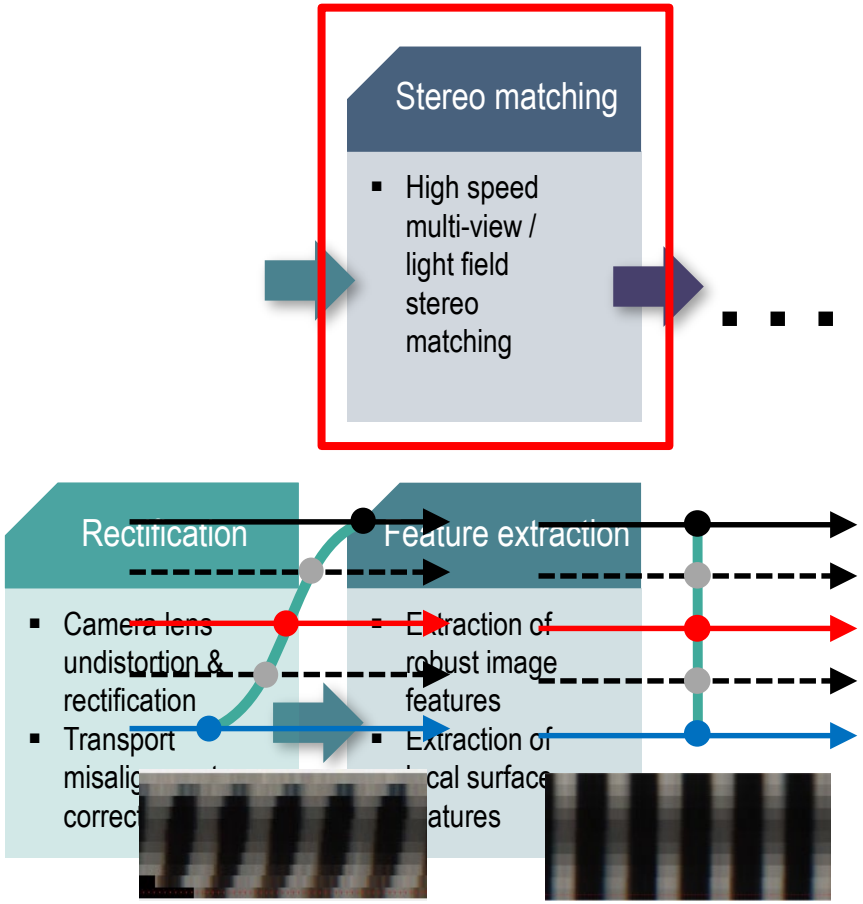
Coarse refinement
- Fast discrete depth denoising / regularization preserving discontinuities

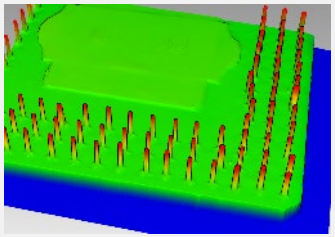
Fine refinement
- Fast continuous depth / regularization
- Fusion with additional depth cues



Refined 2D/3D data
- Fine depth model (depth map, point cloud)
- Depth measurement confidence
- Refined 2D texture images (all-in-focus, gloss / shadow suppression)
- Fine 2.5D surface map

IMPROVED CORRESPONDENCE ANALYSIS

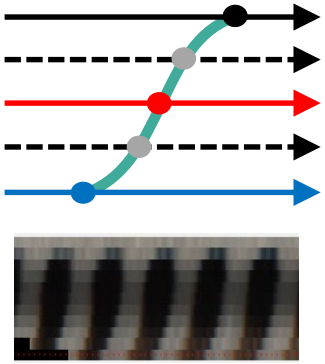




Refined 2D/3D data

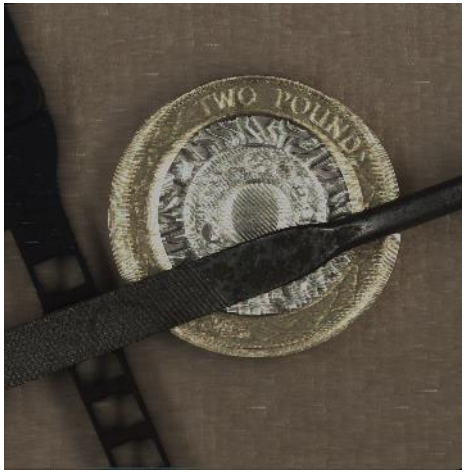
- Fine depth model (depth map, point cloud)
- Depth measurement confidence
- Refined 2D texture images (all-in-focus, gloss / shadow suppression)
- Fine 2.5D surface map

SCENE COMPARISON – IMAGE GRADIENT

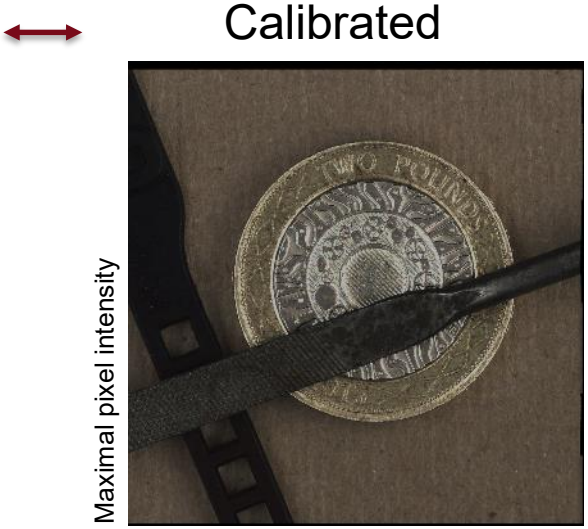


Uncalibrated

Maximal pixel intensity



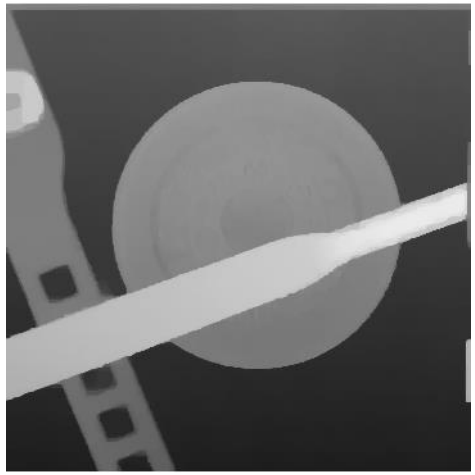
Reconstructed z value after depth denoising

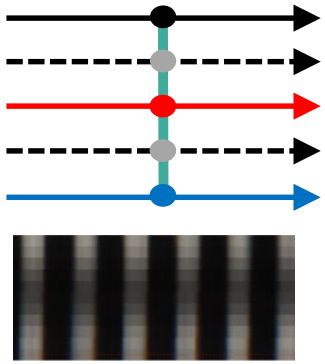


Calibrated

Maximal pixel intensity

Reconstructed z value after depth denoising



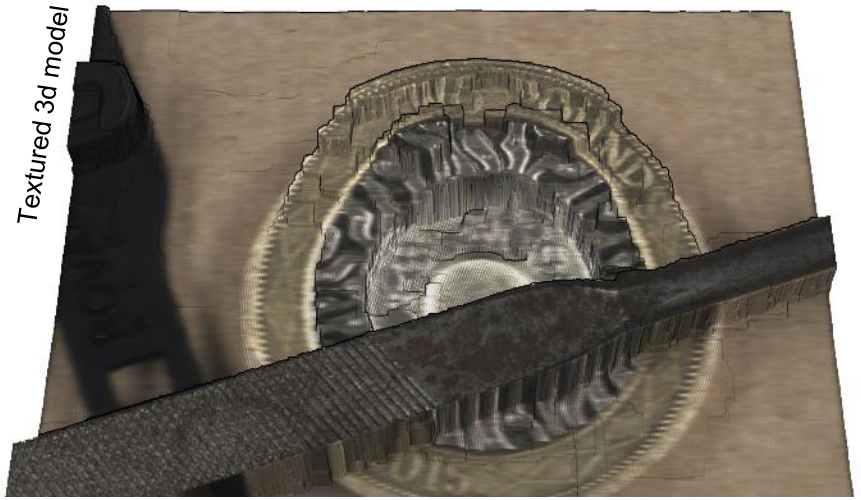


AUSTRIAN INSTITUTE OF TECHNOLOGY

SCENE COMPARISON – 3D RECONSTRUCTION

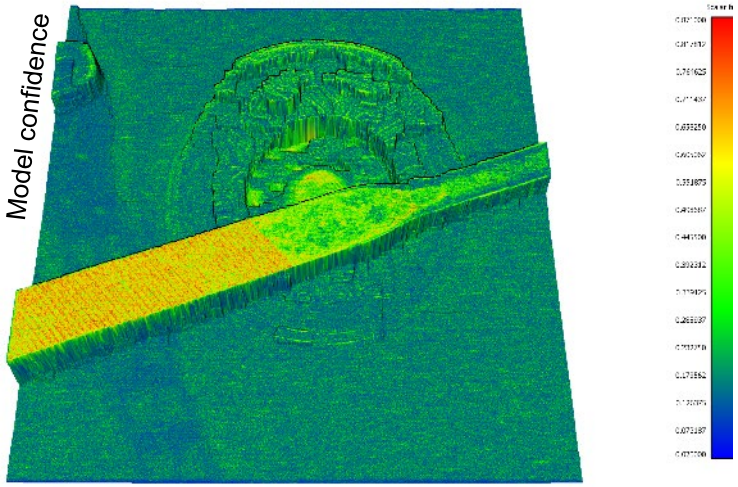
Uncalibrated ⟷ Calibrated

Textured 3d model

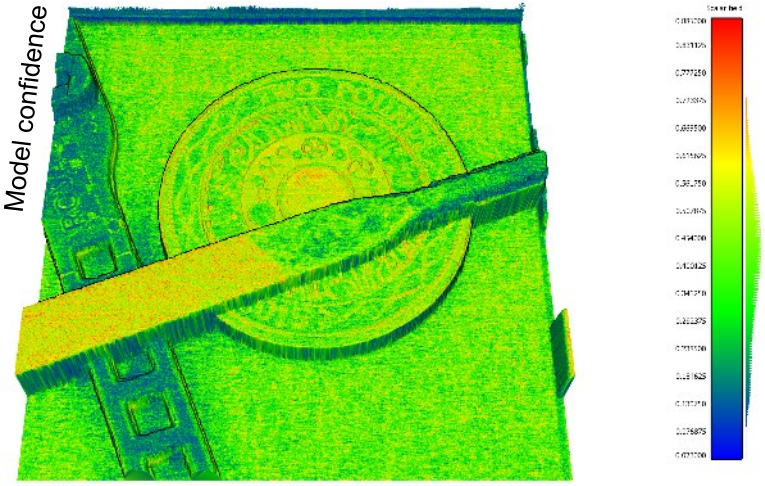


Textured 3d model

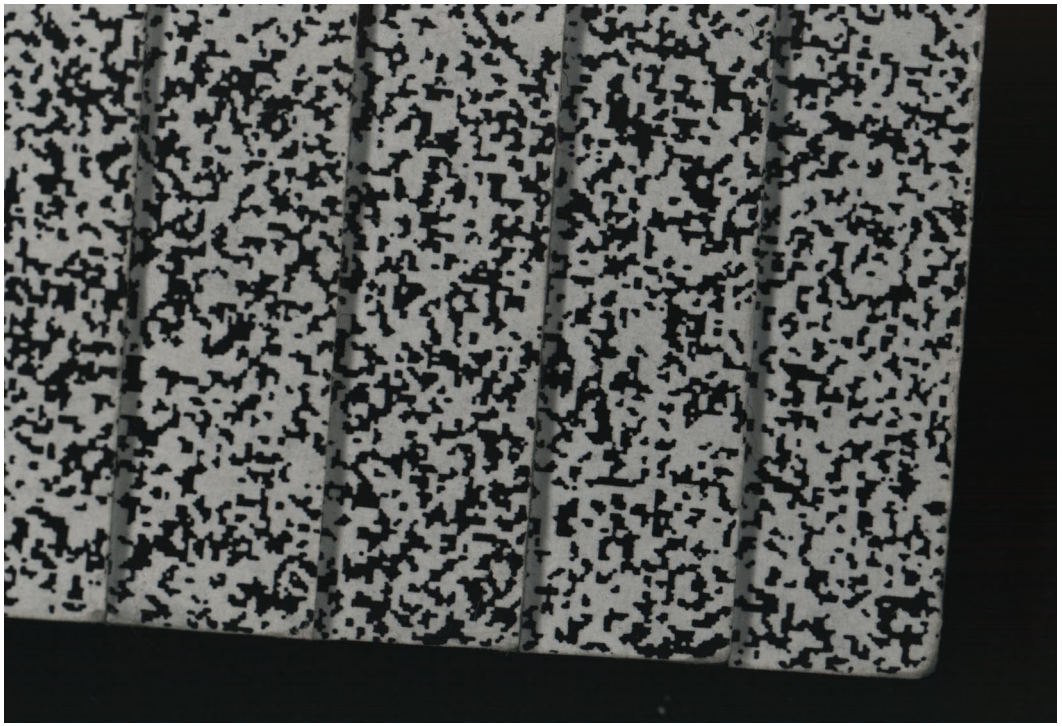
Model confidence



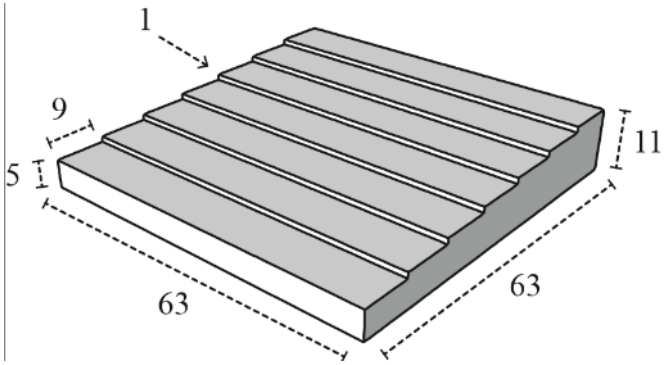
Model confidence



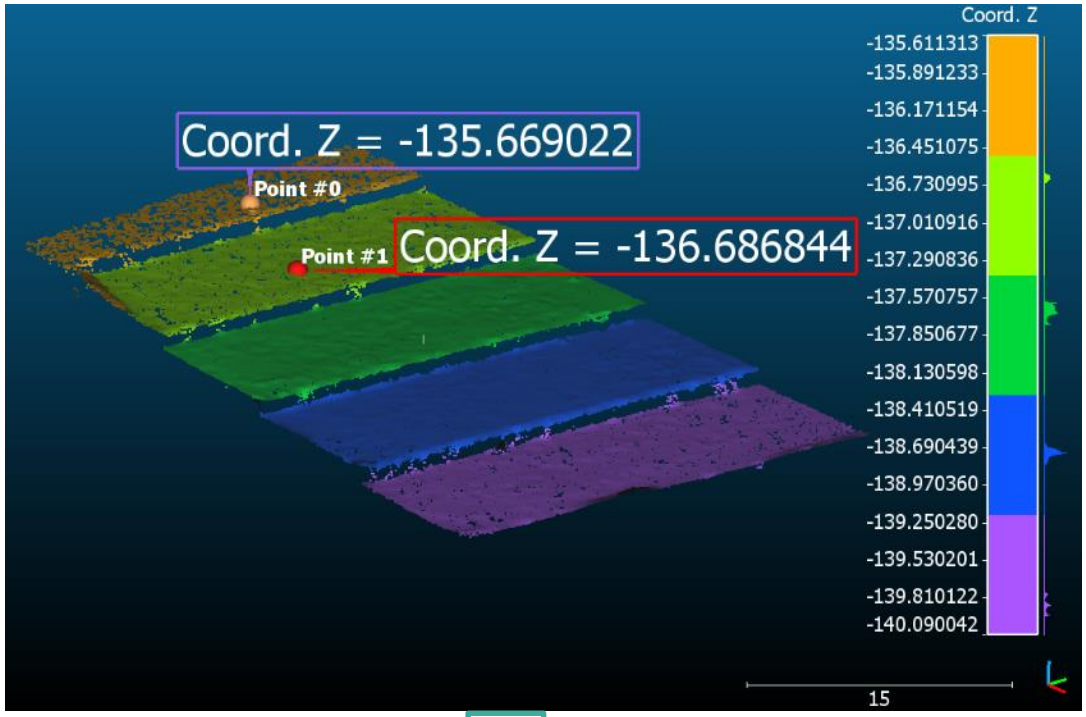
EXAMPLE: STAIRCASE – INPUT LIGHTFIELD STACK



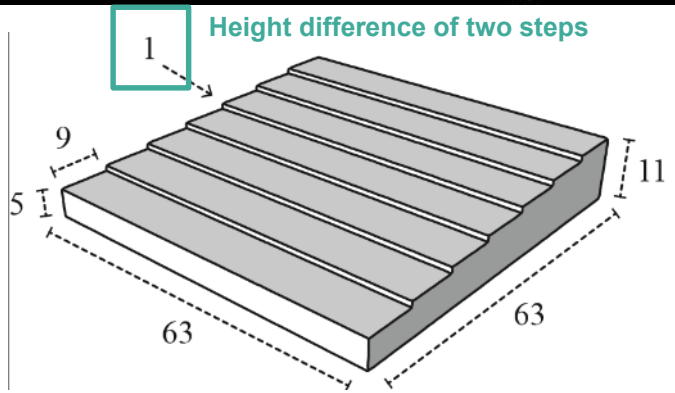
CAD model of the 3d printed model staircase (print tolerance approx. 0.0615mm)



EXAMPLE: STAIRCASE – 3D RECONSTRUCTION

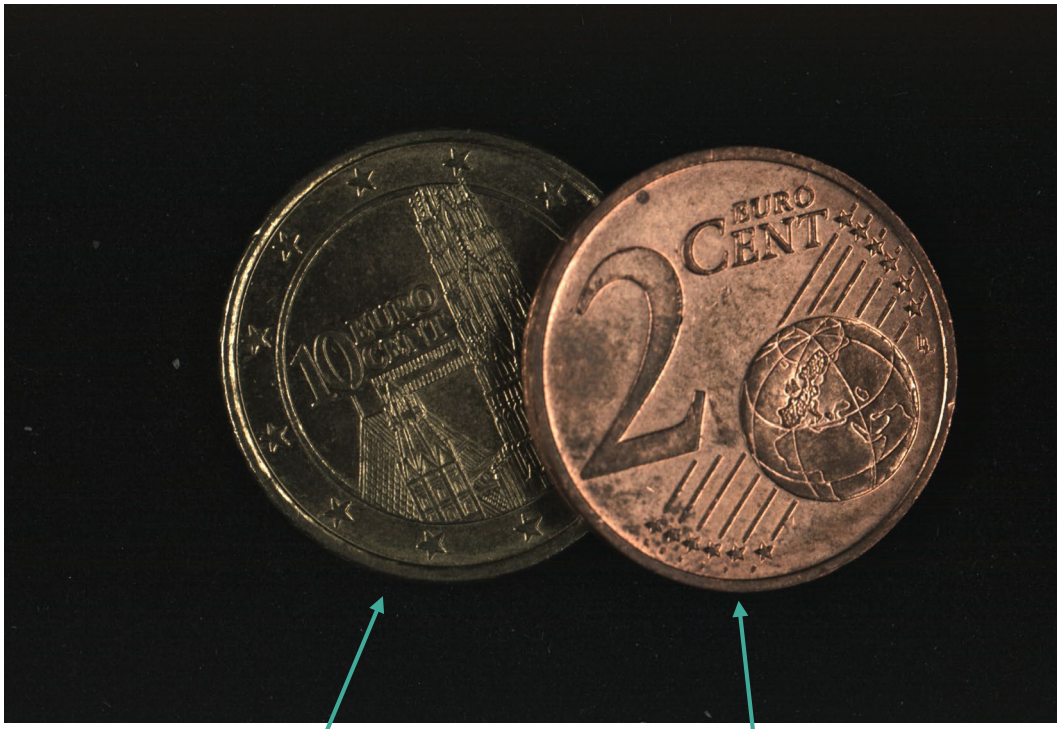


Distance from camera center



AUSTRIAN INSTITUTE OF TECHNOLOGY

EXAMPLE: EURO CENT COINS – IMAGE STACK

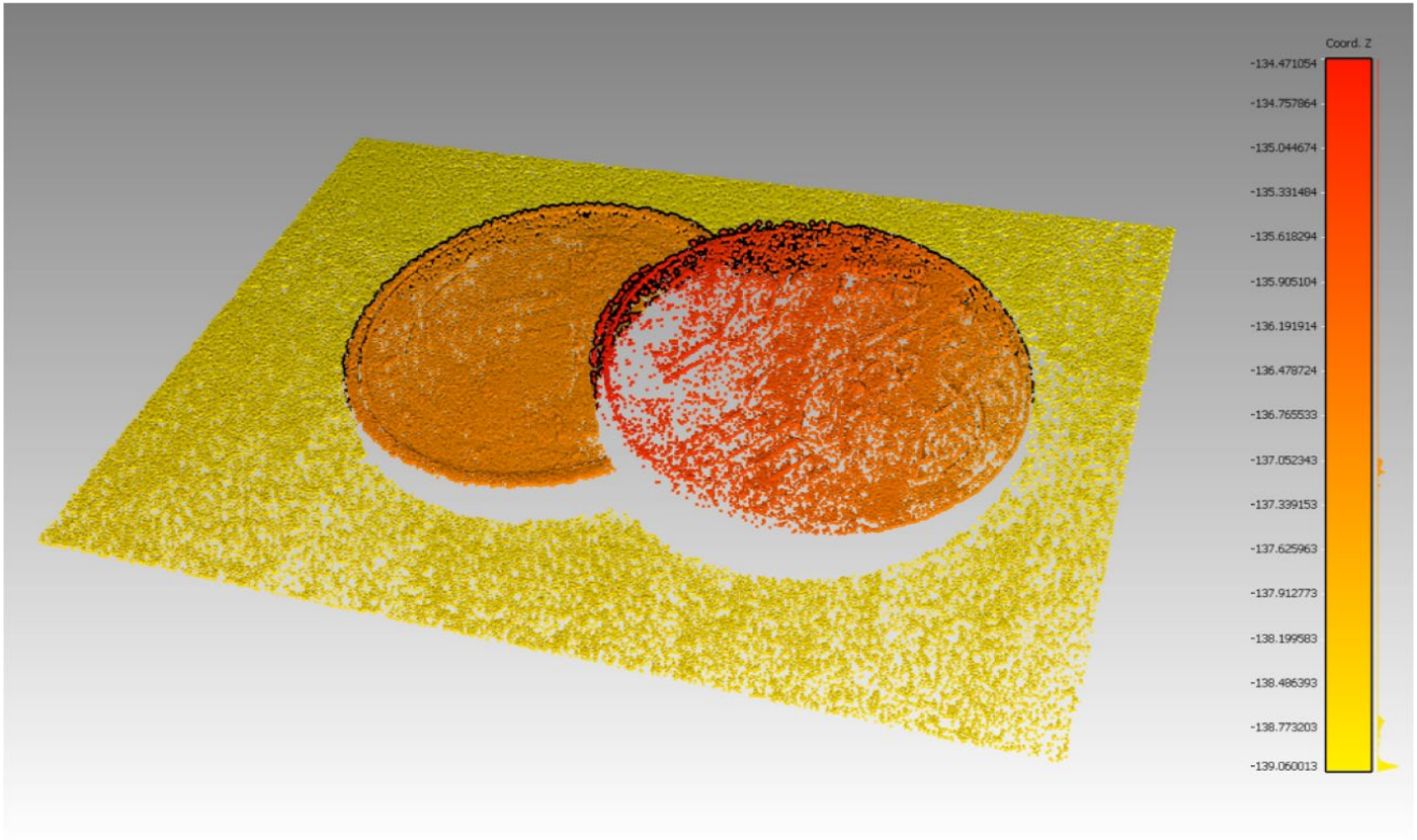


10 Euro Cent coin
Diameter 19.75mm
Thickness 1,93mm

2 Euro Cent coin
Diameter 18.75mm
Thickness 1,67mm

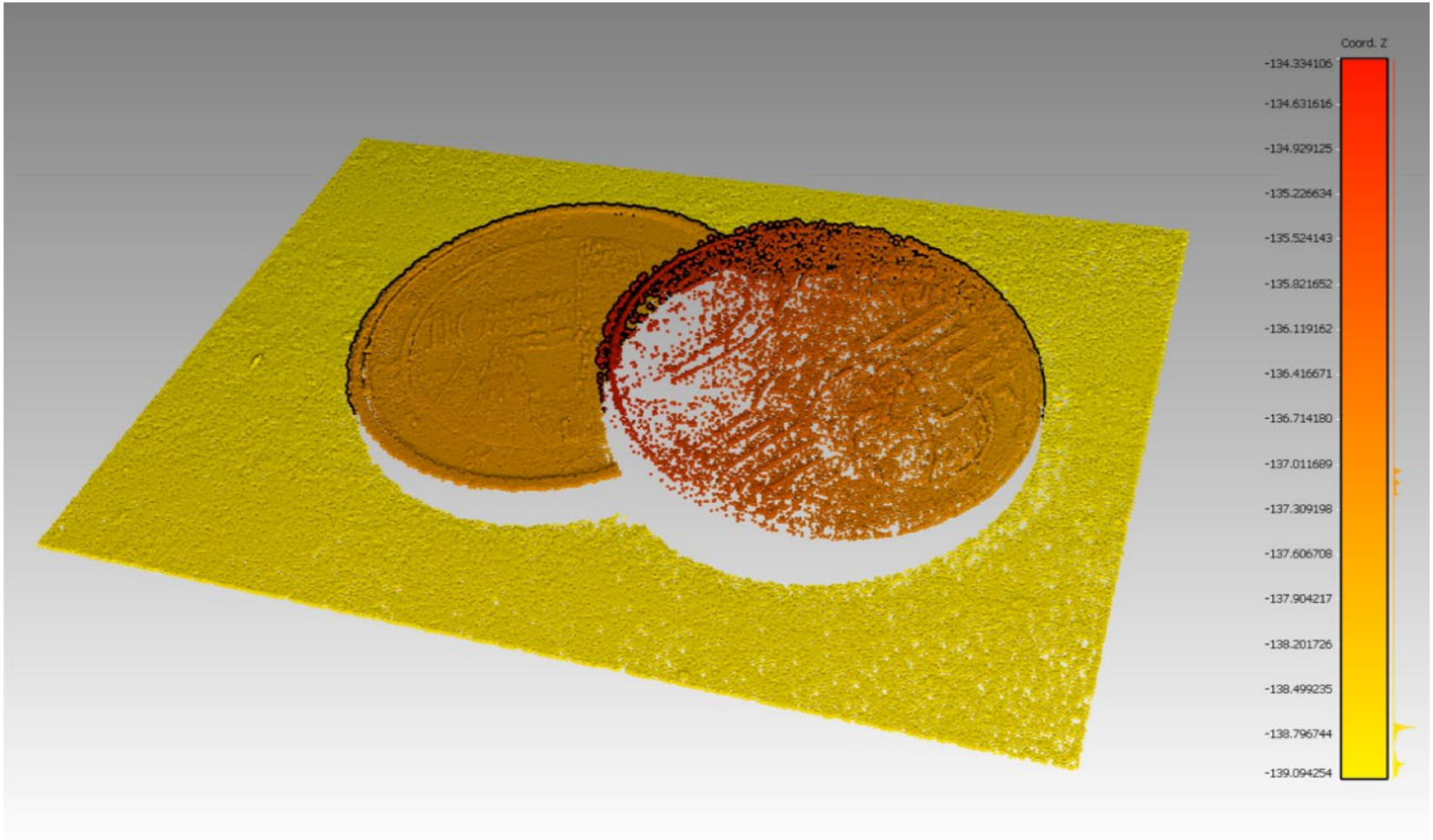
AUSTRIAN INSTITUTE OF TECHNOLOGY

EXAMPLE: EURO CENT COINS - UNCALIBRATED



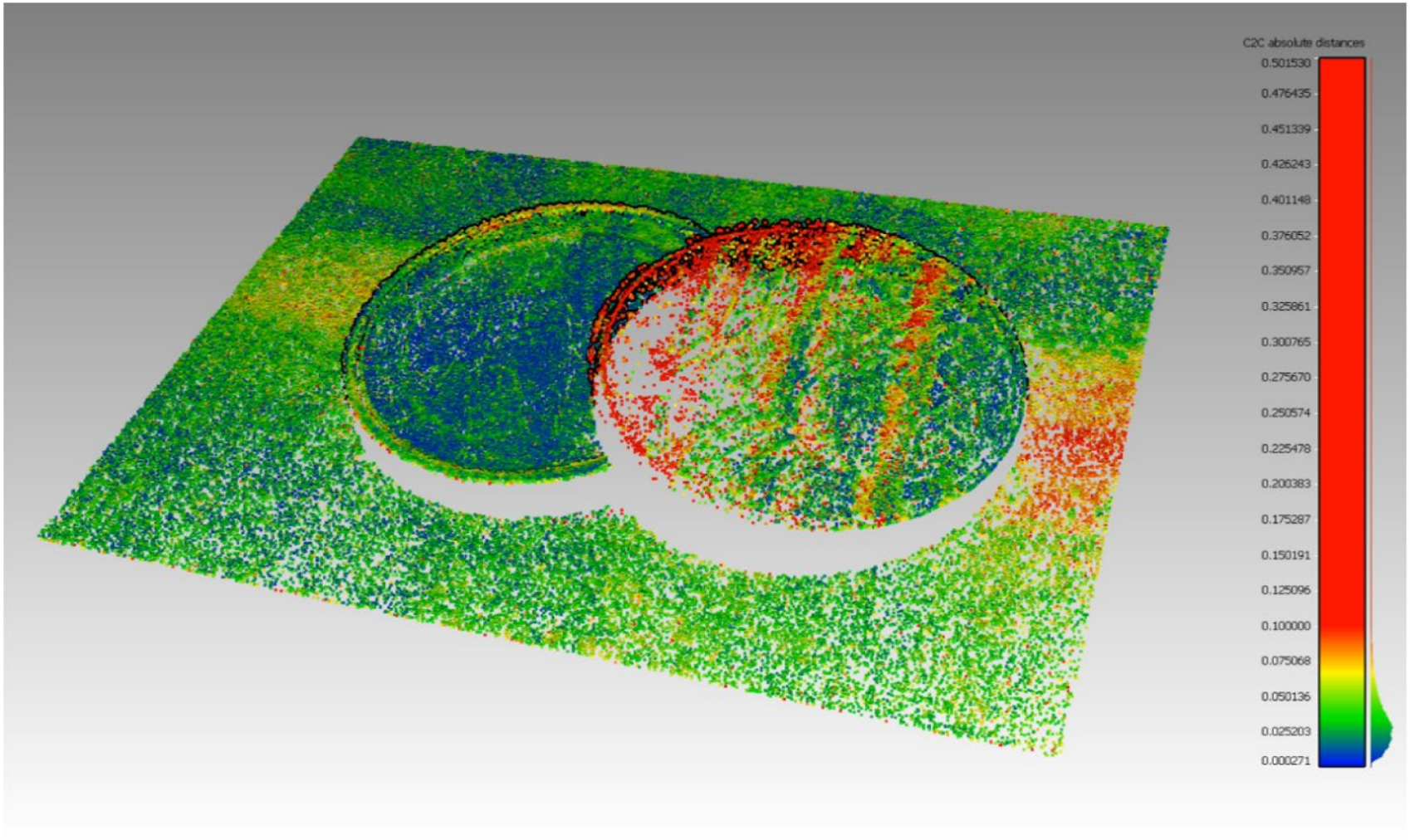
AUSTRIAN INSTITUTE OF TECHNOLOGY

EXAMPLE: EURO CENT COINS - CALIBRATED



AUSTRIAN INSTITUTE OF TECHNOLOGY

EXAMPLE: EURO CENT COINS – ERROR MEASURE

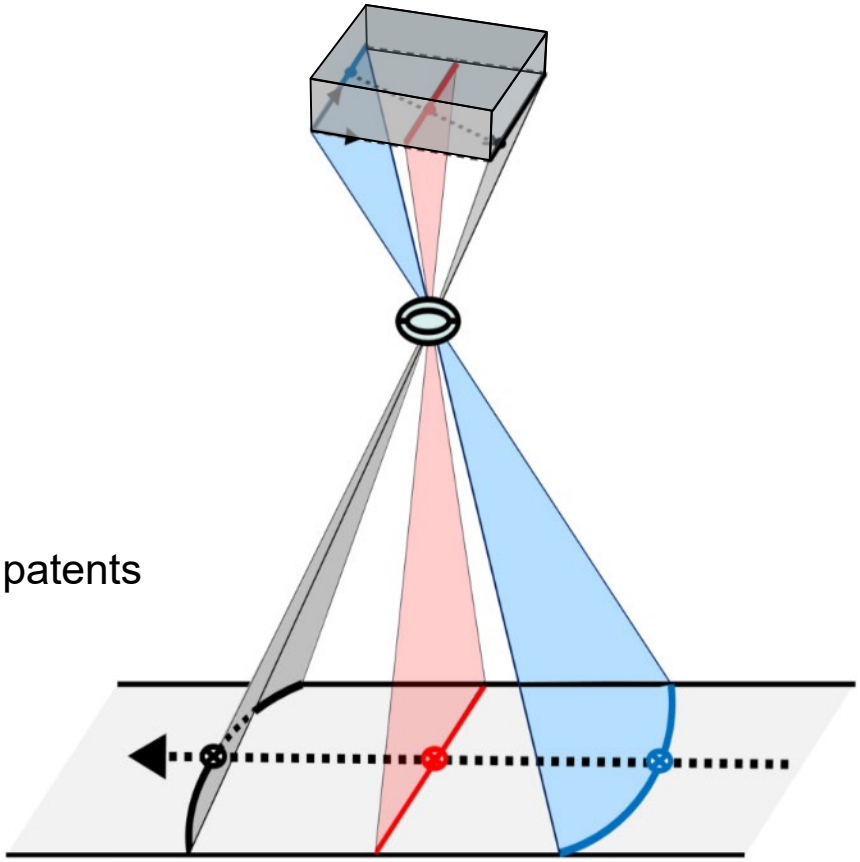


TAKE-HOME MESSAGE

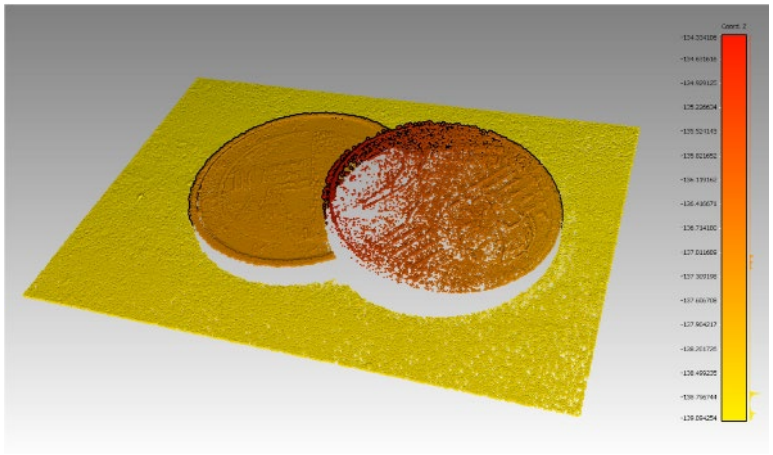
New calibration method turns AIT‘s Inline Computational Imaging system, which uses a single multi-line scan camera to generate **3d light field** stacks into

- a measurement device in **µm-scale**
- at industrial inline **production speed**

For industrial applications, scientific work and our patents visit www.ait.ac.at/hpv



AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY



THANK YOU FOR YOUR ATTENTION!

Bernhard Blaschitz
bernhard.blaschitz@ait.ac.at