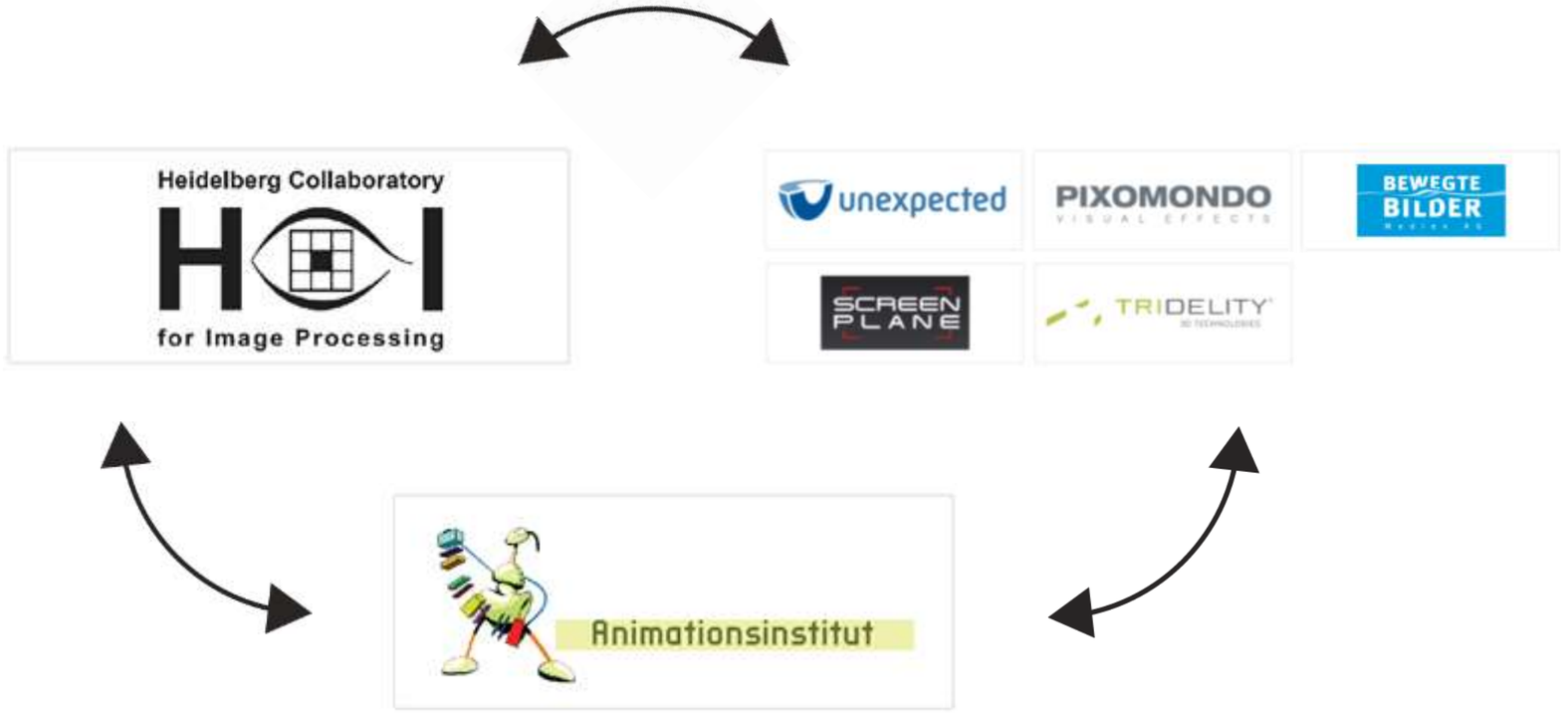
Science Meets Art
Joint Research on Creating Tools for the Stereo/Post-Processing Pipeline

Simon Spielmann, Michael Bußler – Filmakademie Baden-Württemberg

Daniel Kondermann, Rahul Nair – Heidelberg Collaboratory for Image Processing

Tools for the Stereo/post-Processing



“Development of systems and methods for effective creation and processing of stereoscopic content”

- Funded by the Ministry of Economics and 5 companies from Baden-Württemberg
- Research facilities: Filmakademie and Heidelberg Collaboratory for Image Processing
- HCI: development of algorithms for depth estimation, 2D to 3D conversion, ToF Technologie
- Filmakademie: Development of usable software tools and workflows
- Broadly positioned: VFX Companies, camera rig- and display- manufactures

Universities:

Animationsinstitut

Heidelberg Collaboratory for Image Processing

Industry Partner:

unexpected

PIXOMONDO VISUAL EFFECTS

BEWEGTE BILDER Medien AG

Funded by:

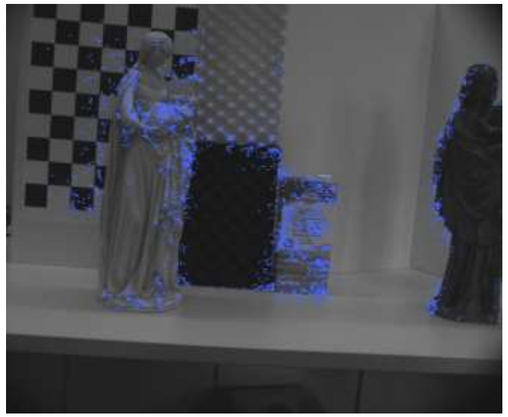
Baden-Württemberg WIRTSCHAFTSMINISTERIUM

SCREEN PLANE

TRIDELITY 3D TECHNOLOGIES

Interactive Algorithms

Using prior knowledge to enhance calculation results

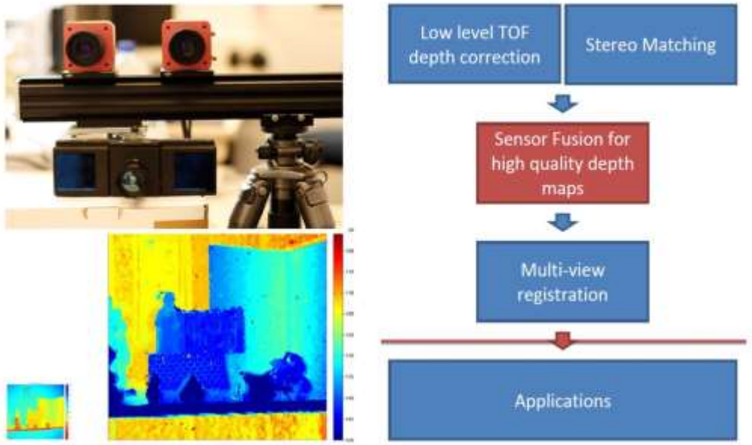


Structure from Motion

2D to 3D conversion: depth estimation and geometry reconstruction based on a set of pictures

Time of Flight (TOF)

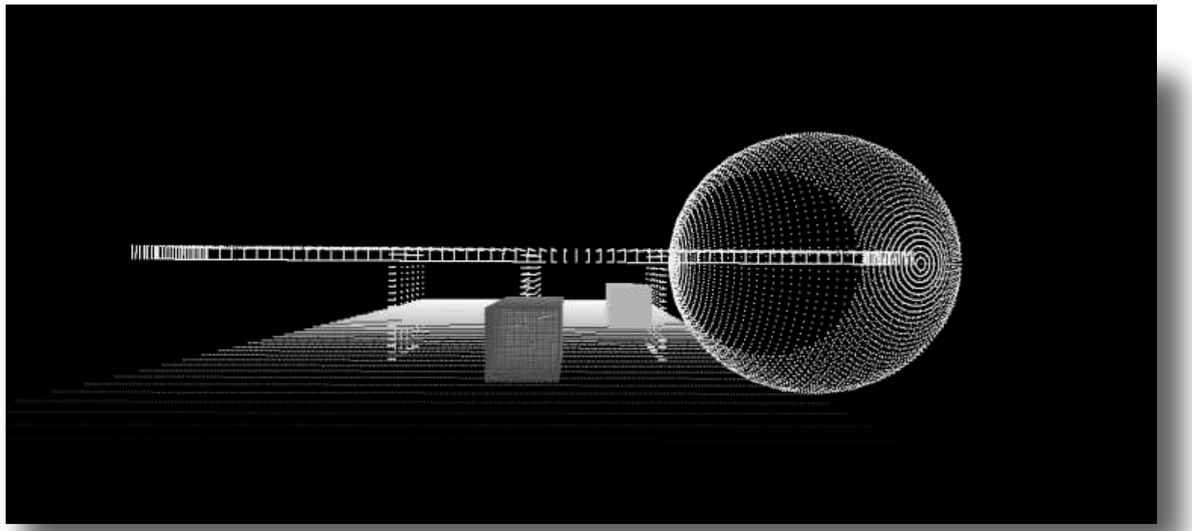
Interactive sensor fusion framework: Combine low-res TOF depth images with high-res color images to enhance quality and resolution of depth maps



DCP: How to get a Girl in 60 Seconds

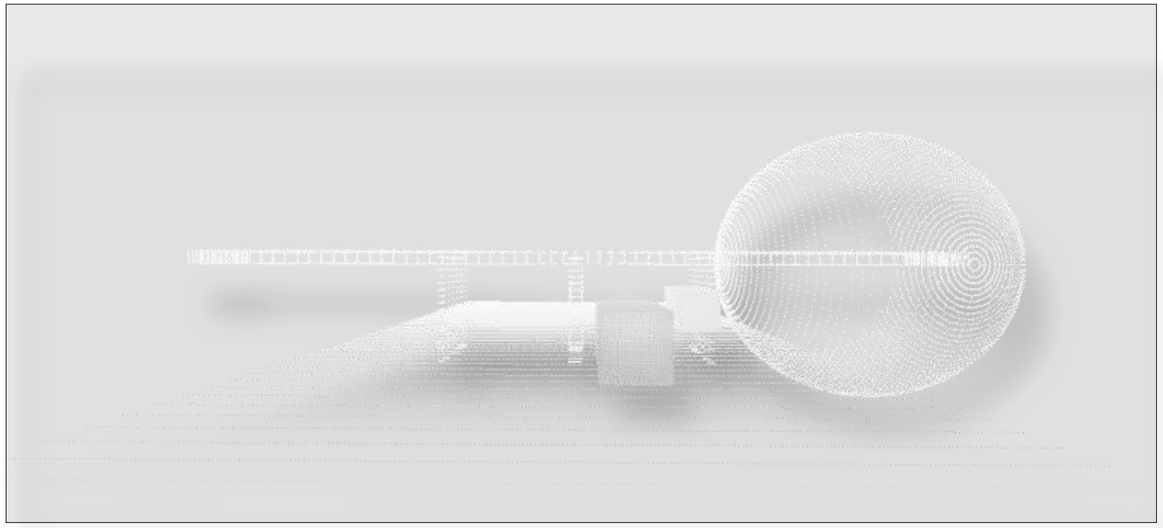
Why Depth Maps?

Project Overview



Why Depth maps? View Synthesis

Project Overview

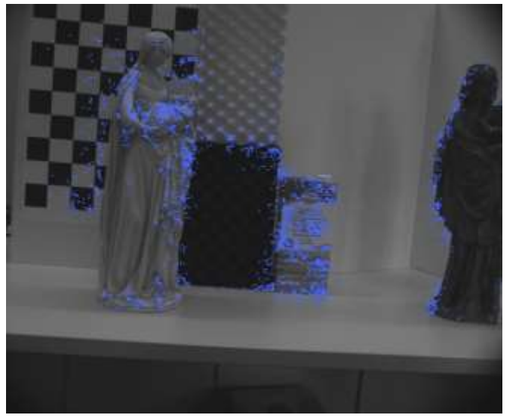


Why Depth maps? CG-Effects

Dinosaur © Ryan North www.qwantz.com

Interactive Algorithms

Using prior knowledge to enhance calculation results

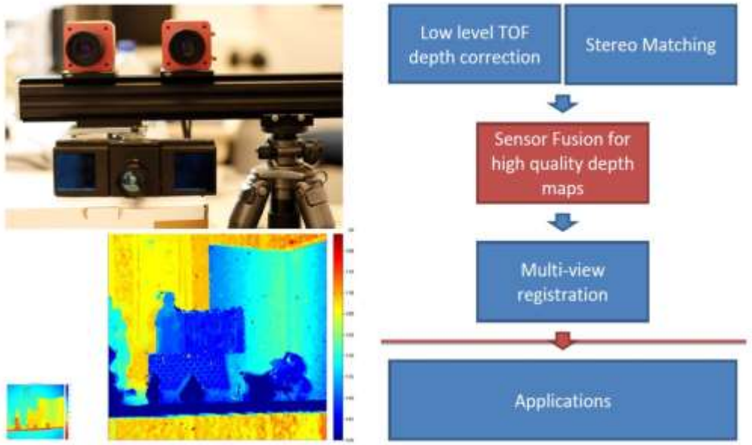


Structure from Motion

2D to 3D conversion: depth estimation and geometry reconstruction based on a set of pictures

Time of Flight (TOF)

Interactive sensor fusion framework: Combine low-res TOF depth images with high-res color images to enhance quality and resolution of depth maps

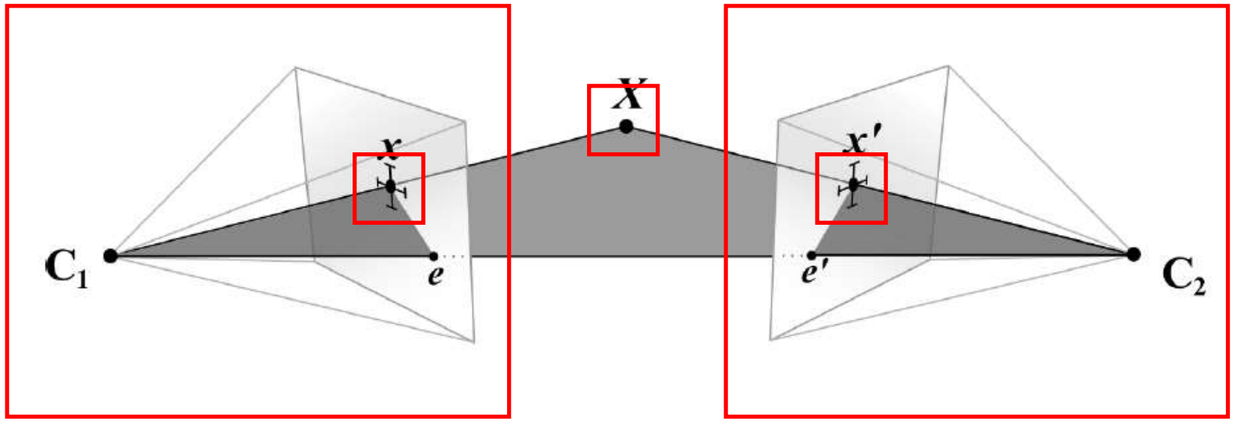


Structure from Motion

Basics

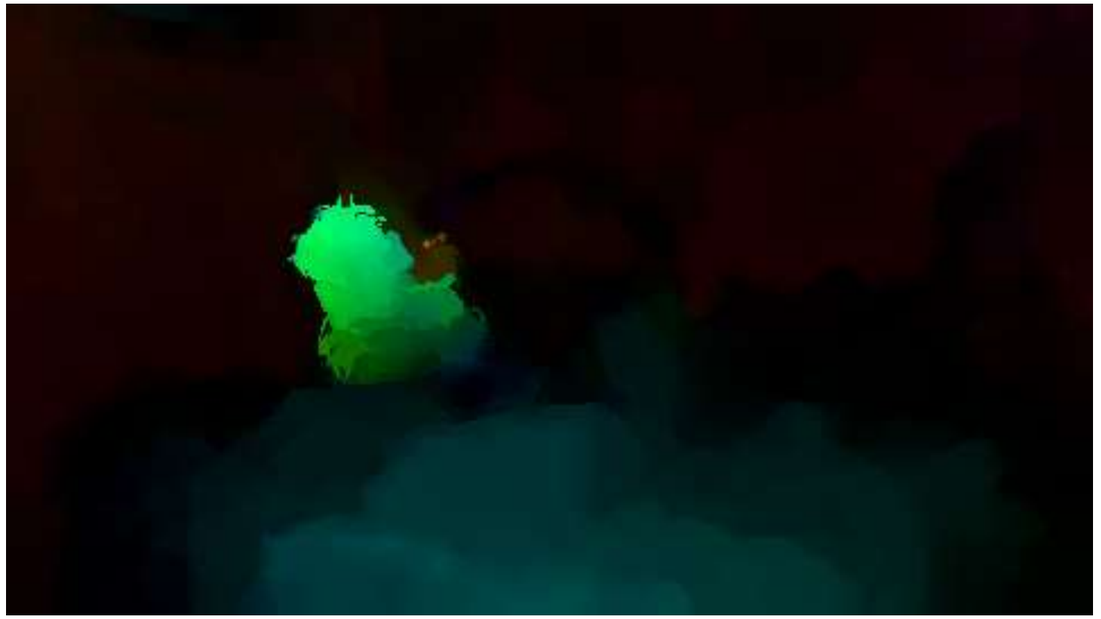
Depth Estimation

- Find correspondent pixels (Fundamental Matrix)
- Estimate camera geometry (Camera Matrix)
- Calculate position of point X by triangulating



But This is Sparse!

What is Optical Flow?



"Bettszene" by Filmakademie Baden-Wuerttemberg.

Goal: Optical flow describes the motion of image elements.

Central problem: *What* are these image elements? (single pixels, pixel clusters, regions…)

Our application: Estimating scene structure (depth) from motions.

Data term, ensuring constancy of some moved image property over time, e.g. BCC:

$$\int_{\Omega} \Phi\left(\left(I_x \cdot u + I_y \cdot v + I_t\right)^2\right) \mathrm{d}\vec{x} \overset{u,v}{\longrightarrow} \min$$

Prior term ensuring smoothness of sought motion field:

$$\int_{\Omega} \delta(\vec{x}) \cdot \Phi(\|\nabla u\|_2^2 + \|\nabla v\|_2^2) \, \mathrm{d}\vec{x} \overset{u,v}{\longrightarrow} \min$$

Various **optimization methods**: Newton, Conjugate Gradients, PetSc, …

Central Problem: Over-Regularization of Depth Edges

Main Reason: Estimation Algorithm has no knowledge about scene structure

Annotate on 1st frame

Learn on 1st Frame

Learn Algorithm

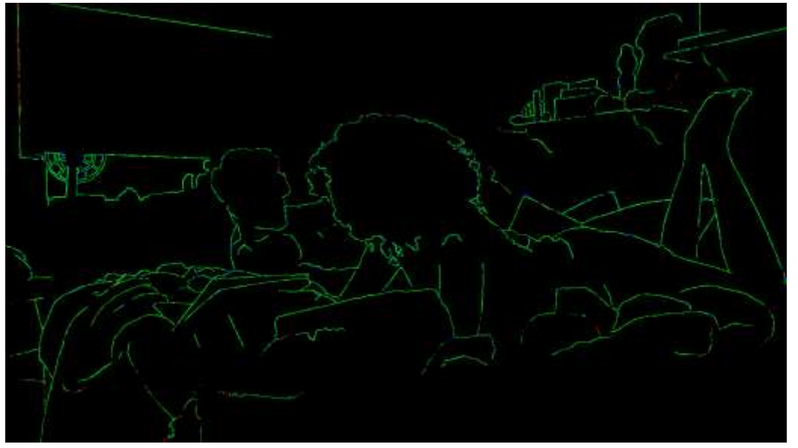
Predict Depth Edges for all other frames

Optical Flow

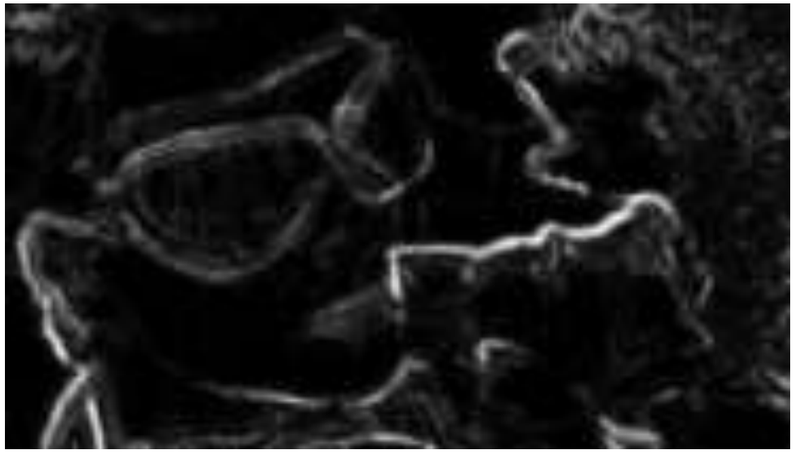
Depth Edge Results

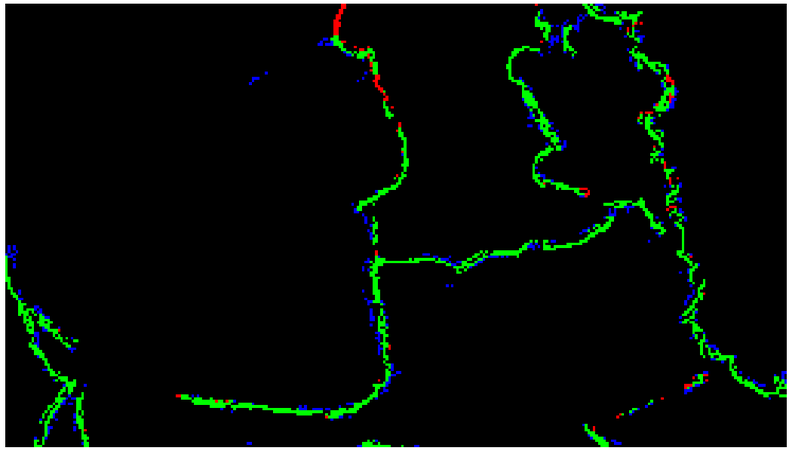
Probabilities

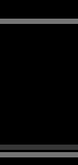
Edges after Post Processing



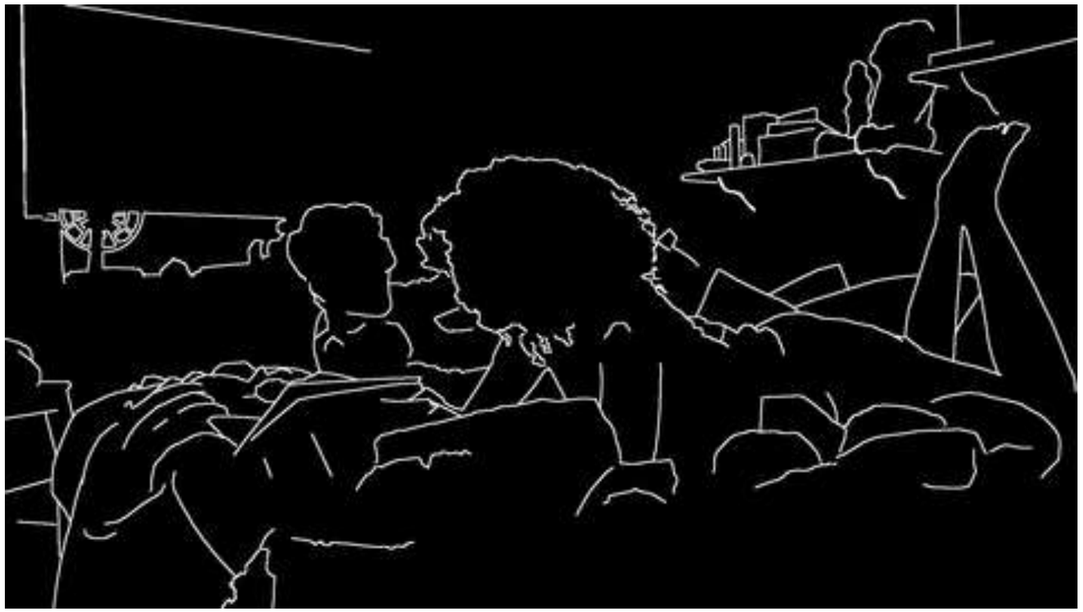
Comparison with Ground Truth

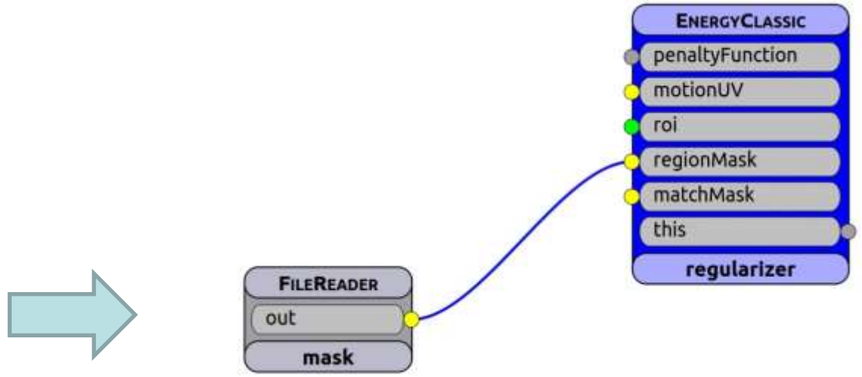






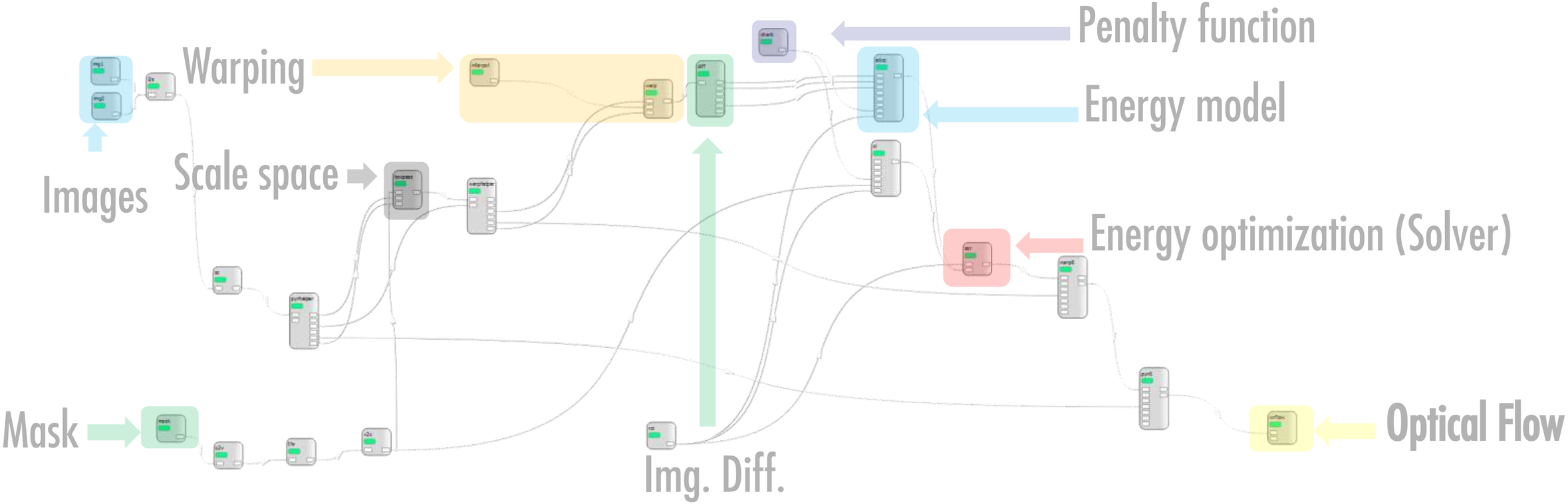
In order to prevent over-regularization, simply connect regularization mask to regularizer module.





Optical Flow

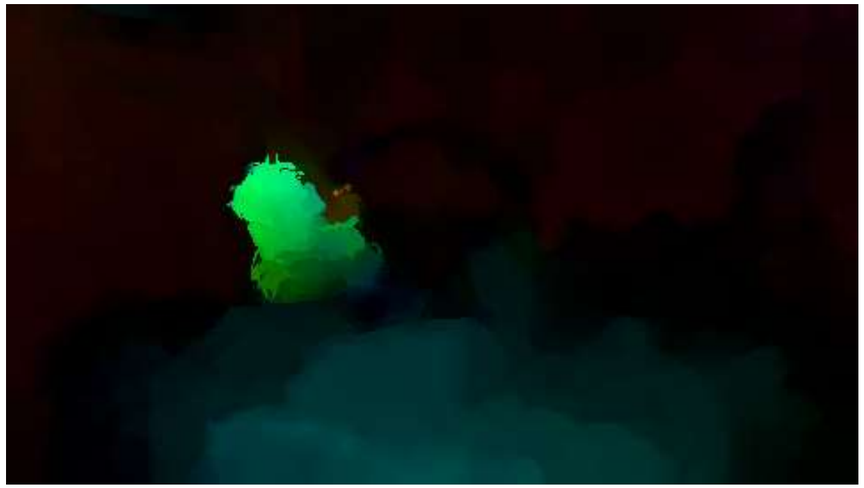
Workflow



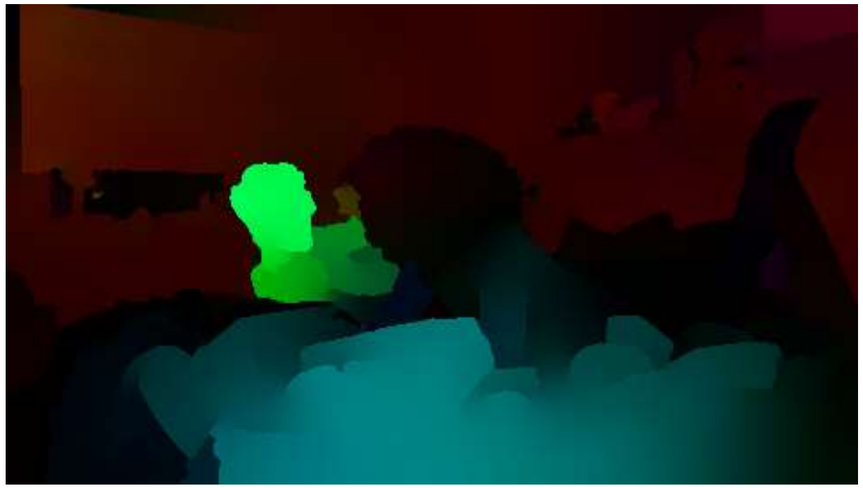
depicted is a very simple **Horn&Schunck**-like algorithm for optical flow estimation,
enhanced by regularization mask support developed at *University of Heidelberg (IWR/HCI).*

Optical Flow

Algorithm Compaison



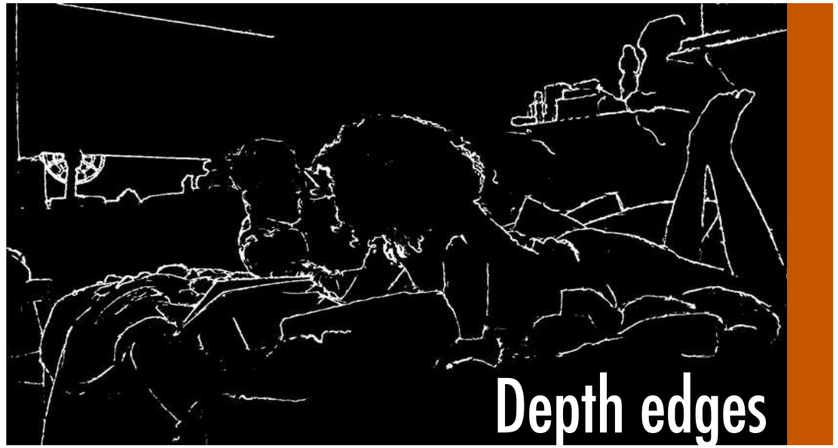
One of the best automatic algorithms for optical flow estimation,
Classic+NL,
proposed by Deqing Sun in 2010.

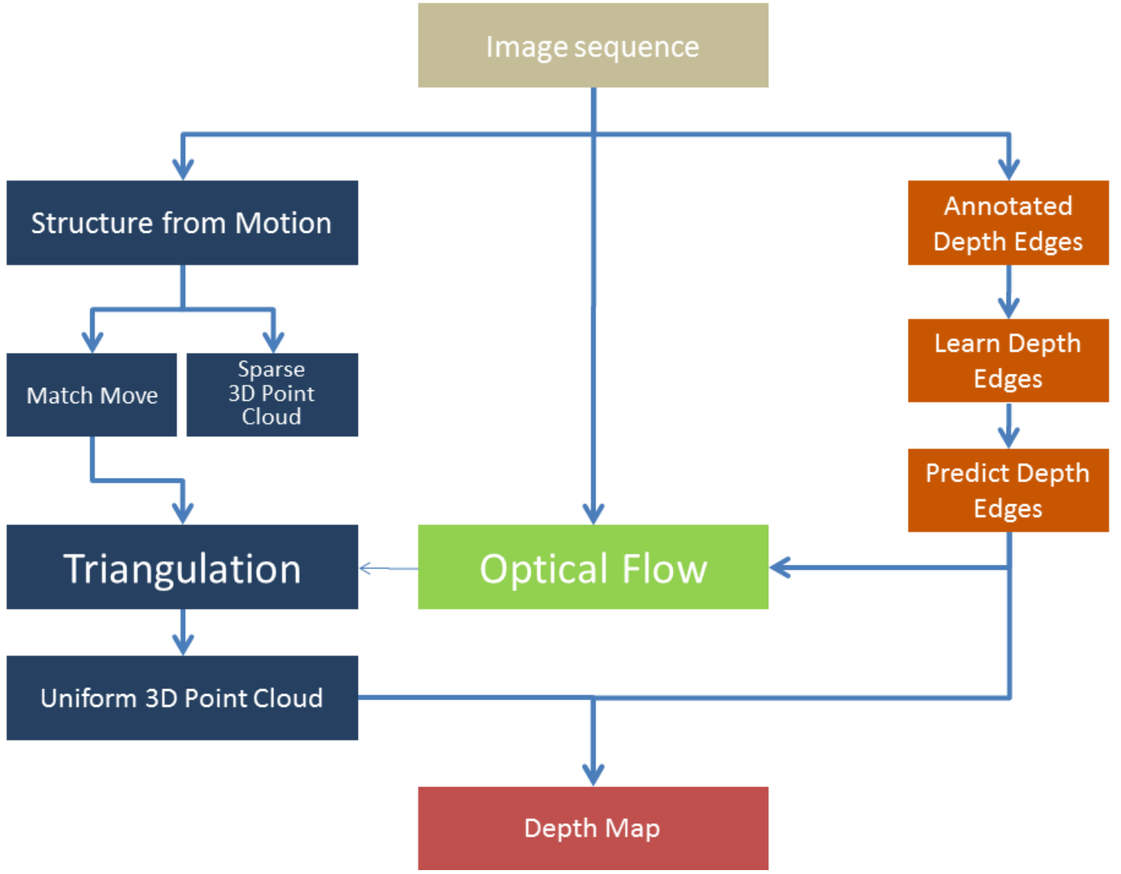


One of the worst automatic algorithms for optical flow estimation,
Horn&Schunck,
enhanced by regularization mask support by HCI Heidelberg.

Tools for the Stereo/post-Processing

Depth Edges for Dimensionalization

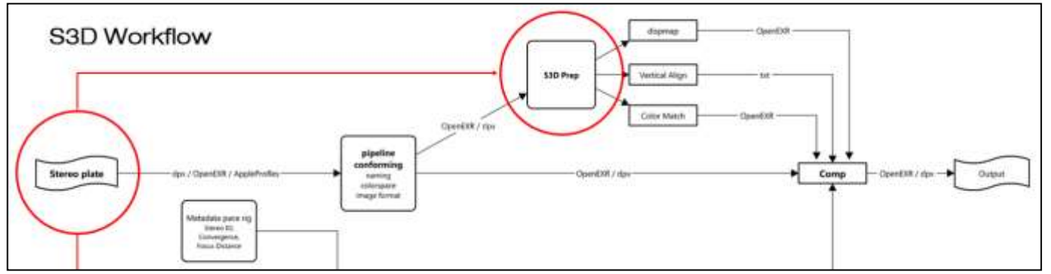




Up Next: Michael

Production Pipeline

Integration in the S3D Production Workflow



Frapper

Interactive Algorithms with the Filmakademie Application Framework

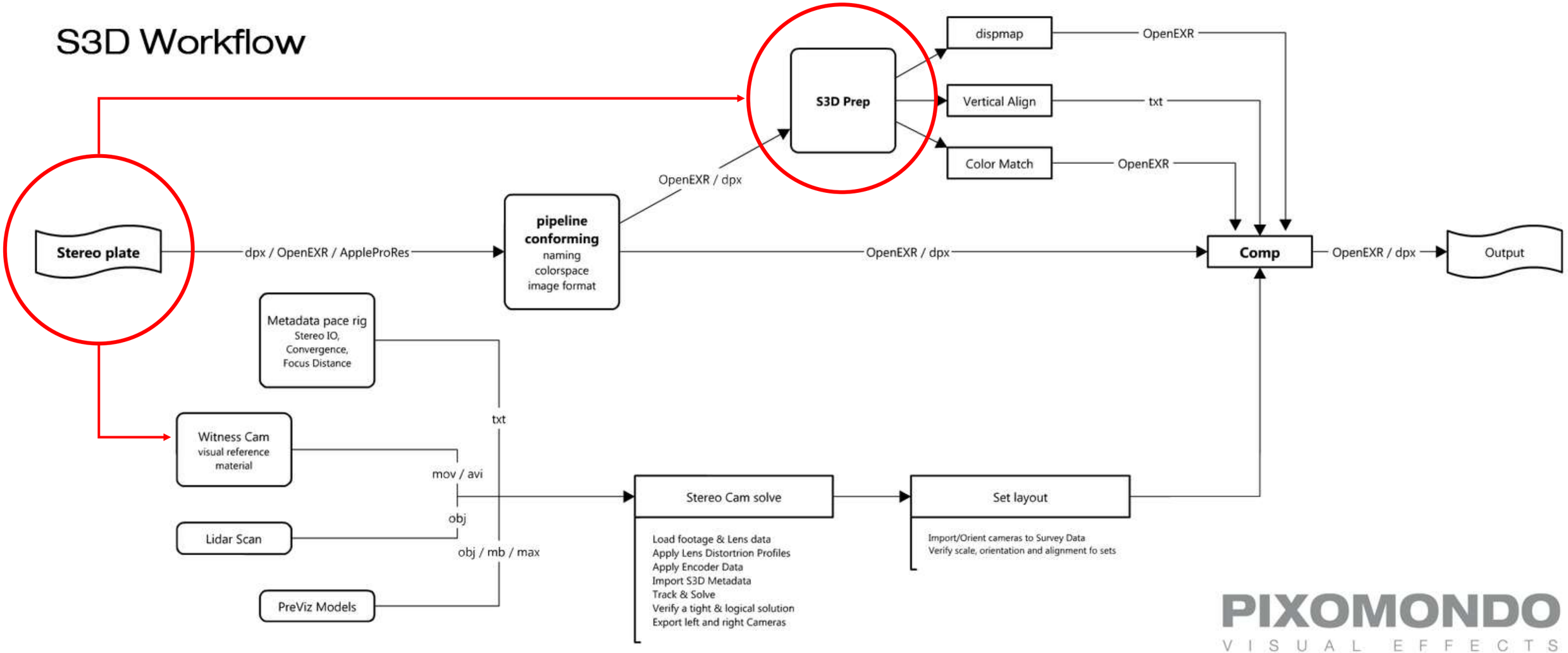
Interactive 2D to 3D Conversion

Results of the 2D to 3D Interactive Conversion Workflow

Tools for the Stereo/post-Processing

Production Pipeline

S3D Workflow



PIXOMONDO
VISUAL EFFECTS

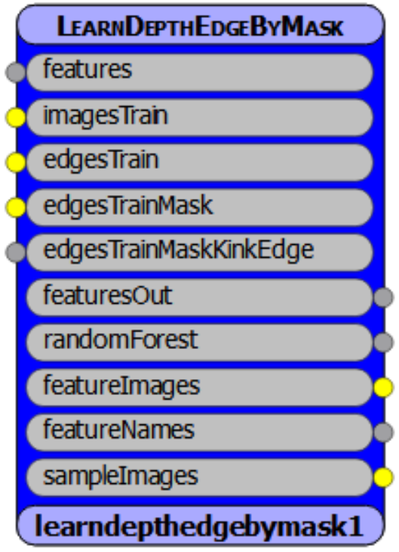
Frapper Features

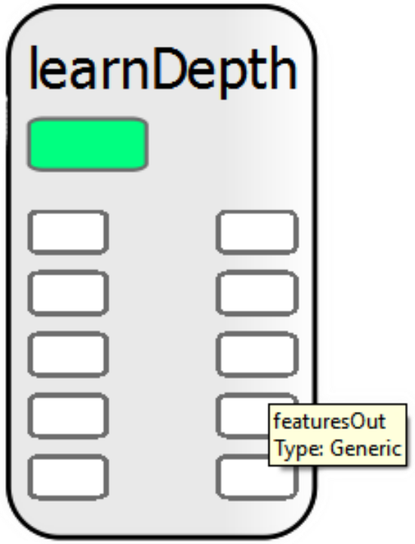
- Node-based Application Framework developed by R&D at Filmakademie
- **Open Source Software (under LGPL 2.1)**
- Cross-Platform with CMake, Qt and Ogre3D (all OSS)
- Modular framework concept → Node-,Panel- & Widget Plugins
- Focus on **3D real-time applications**
- Compositing & Shading Framework (DX/OGL)
- Asset pipeline with established DCC Tools via Ogre Exporter and Alembic Export
- Supports **NVIDIA 3D Vision** and **Tridelity Autostereoscopic Displays**
- **Wrapper for HCI Toolkit Charon**

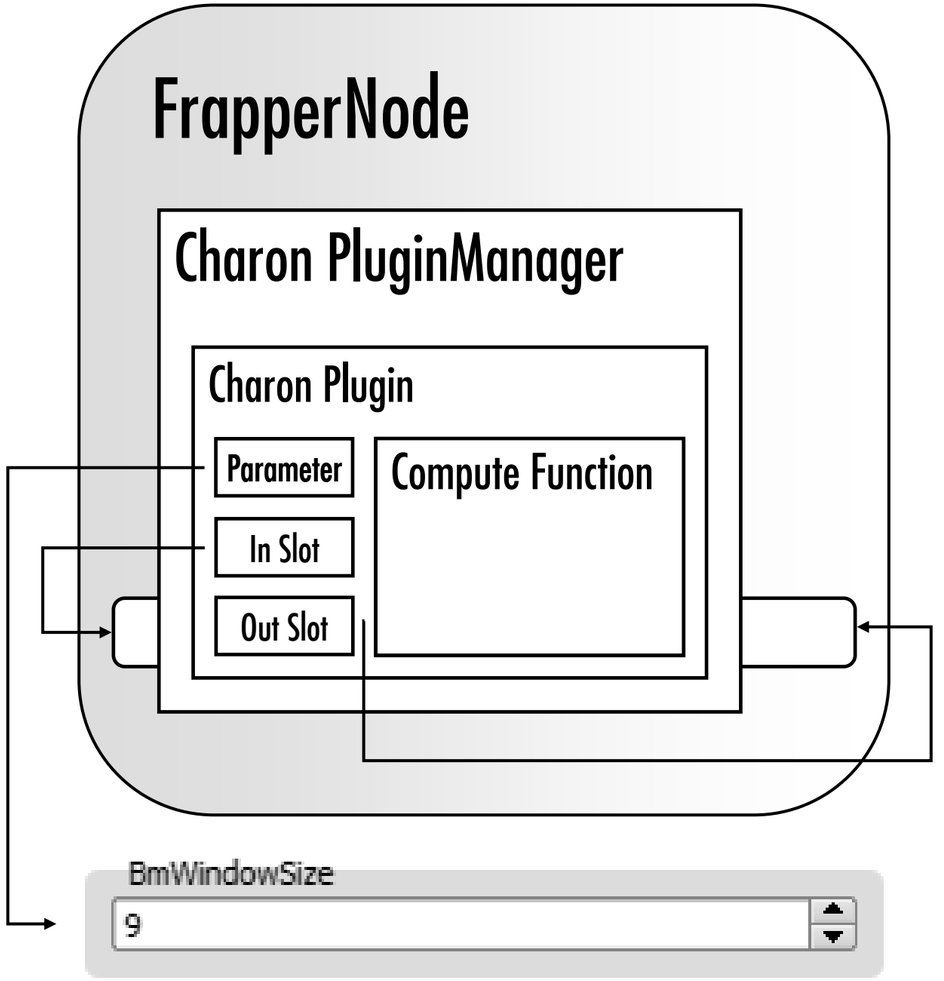
http://frapper.sourceforge.net

FrapperNode

- Load and Process Charon Nodes in Frapper
- Direct Mapping of Charon Slots and Parameters
- Embed and Execute Charon Workflows from Frapper
- Python Wrp2Dae Converter Script
- Collaborative Coding and Simplified Data Exchange







Tools for the Stereo/post-Processing

Shot 260: Bed Sequence

Tools for the Stereo/post-Processing

User Interaction

Tools for the Stereo/post-Processing

Predicted Depth Edges

Tools for the Stereo/post-Processing

Resulting Depth Maps

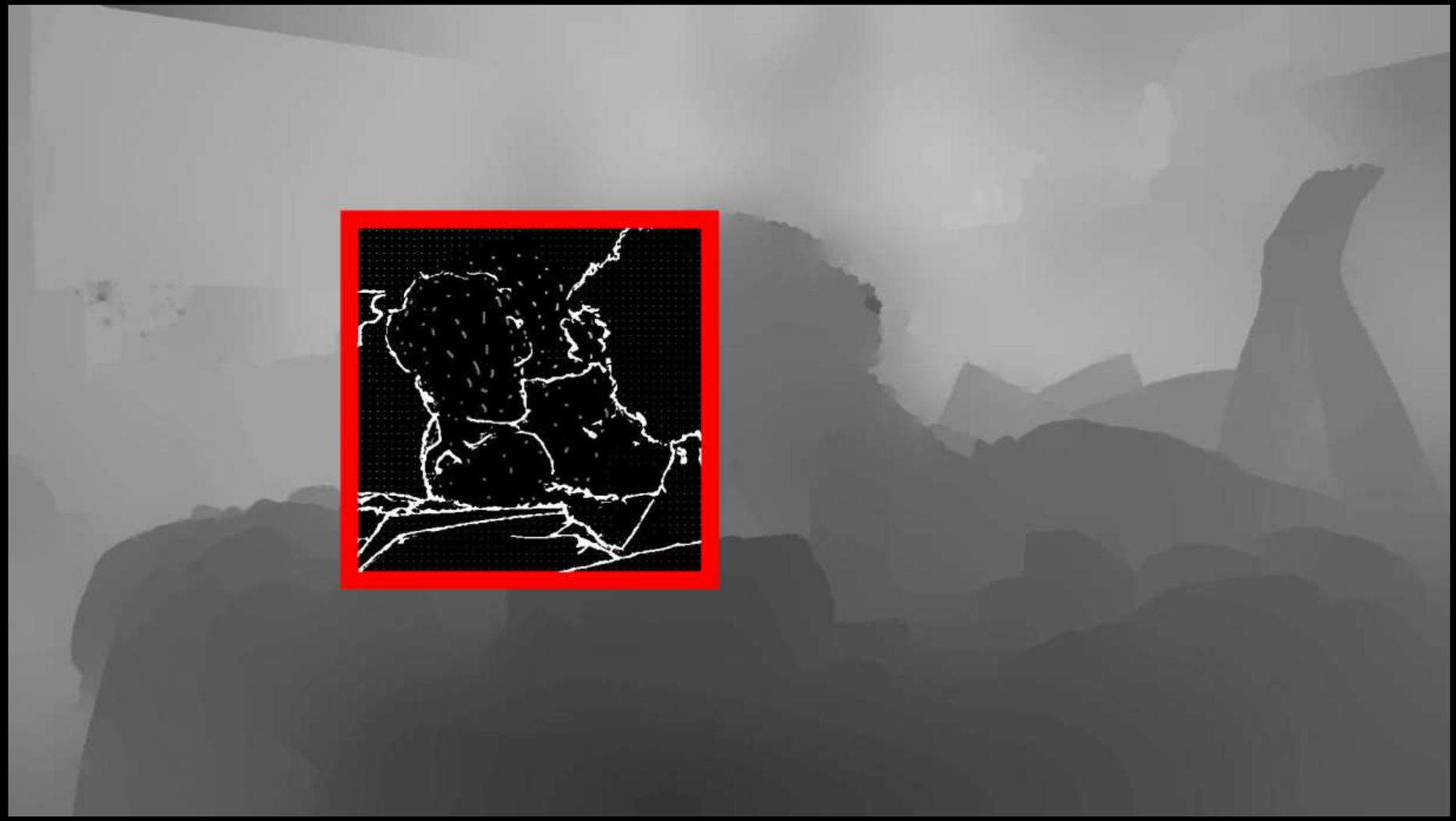
DCP Shot260 Converted (Sq260-DM-075)

User Scribble

Tools for the Stereo/post-Processing

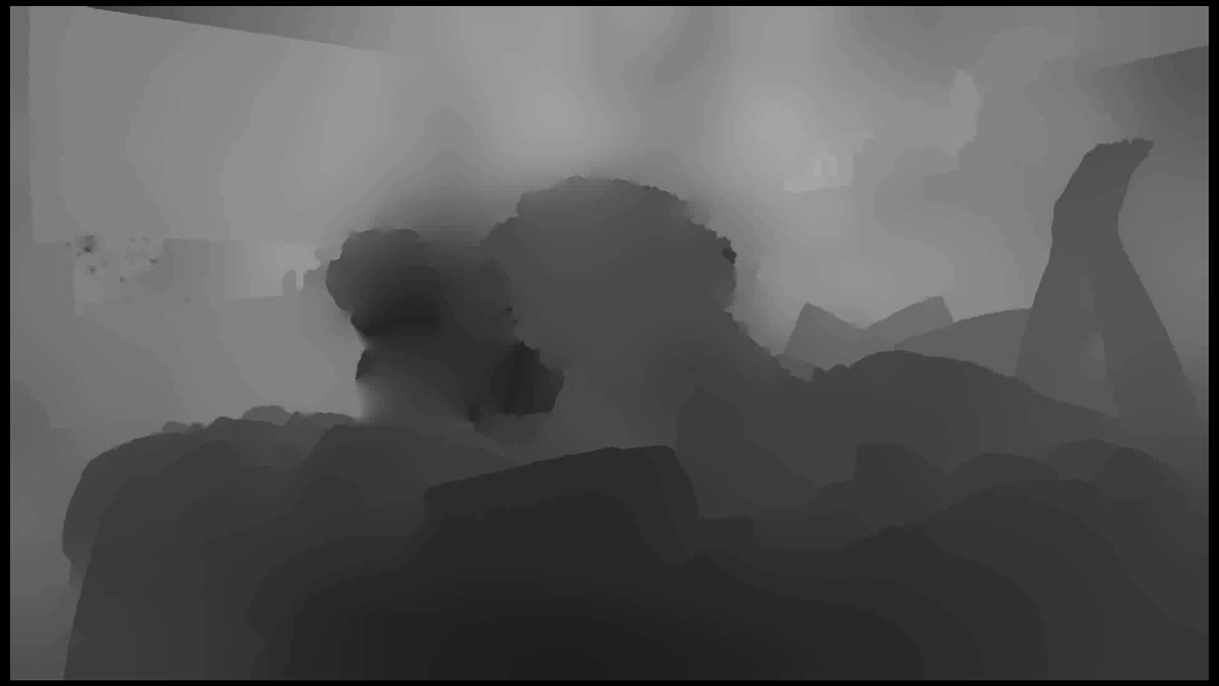
User Scribble

User Scribble



User Scribble

Resulting Depth Maps



Original

With User Scribble

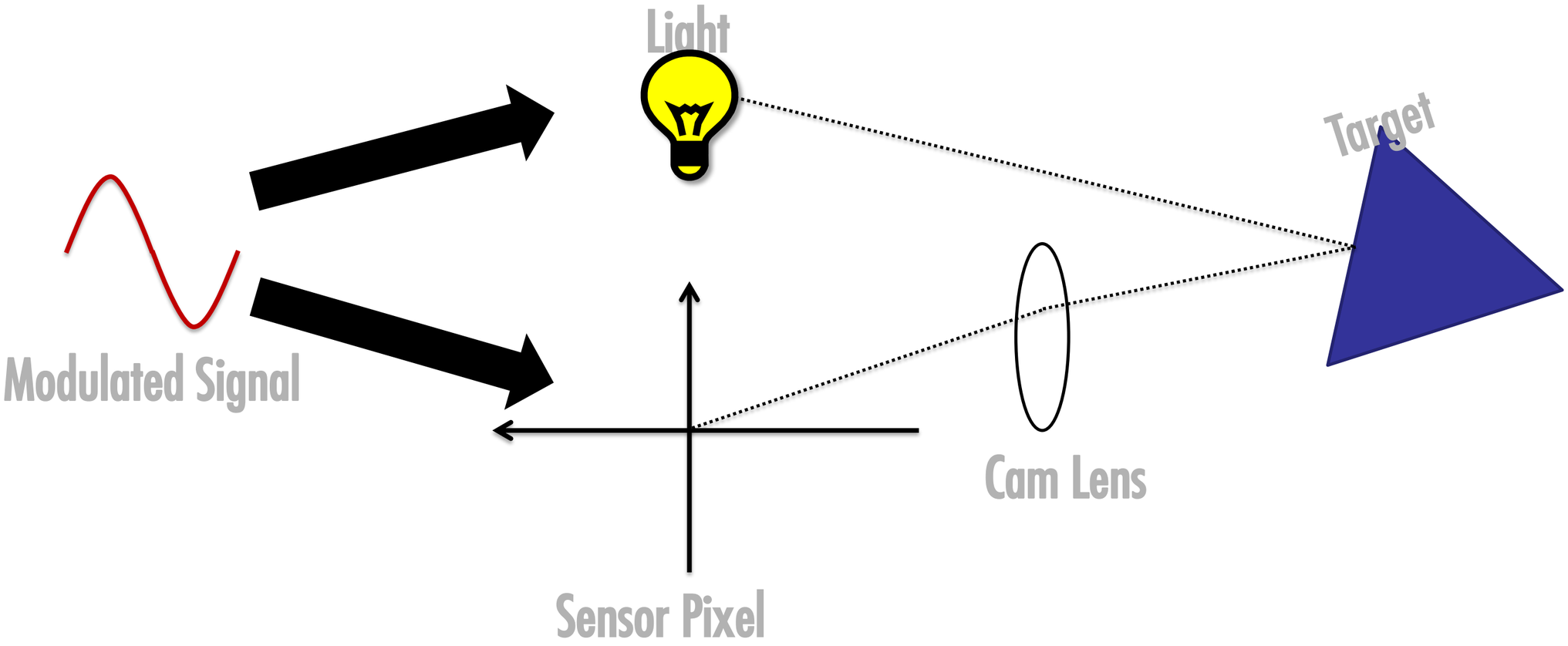
DCP Shot260 Converted with User Scribble (Sq260-DM-US-075)

Back to Rahul

Time of Flight

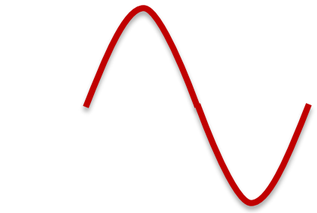
Time of Flight

Working Principle

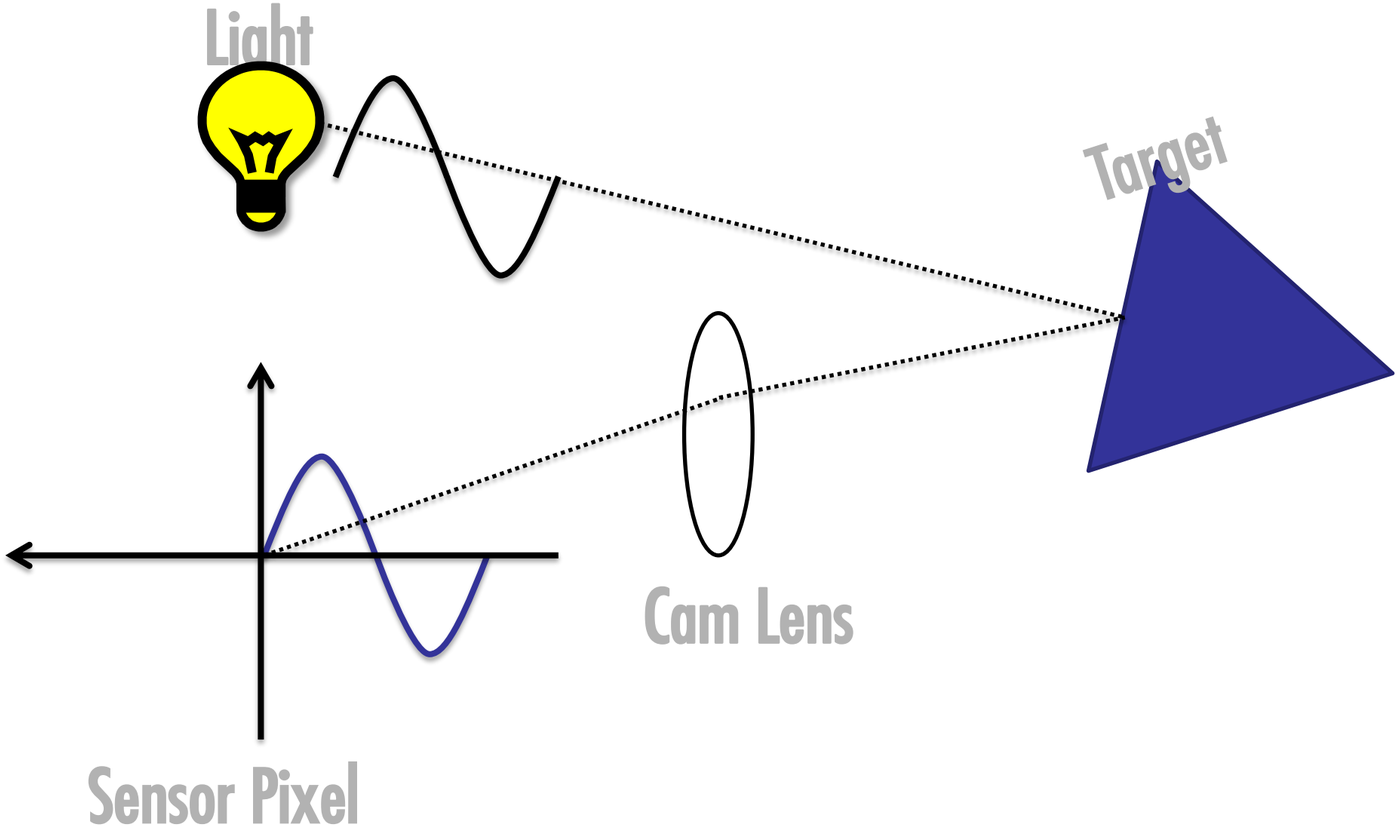


Time of Flight

Working Principle

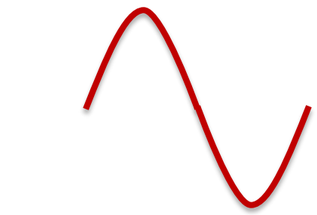


Modulated Signal

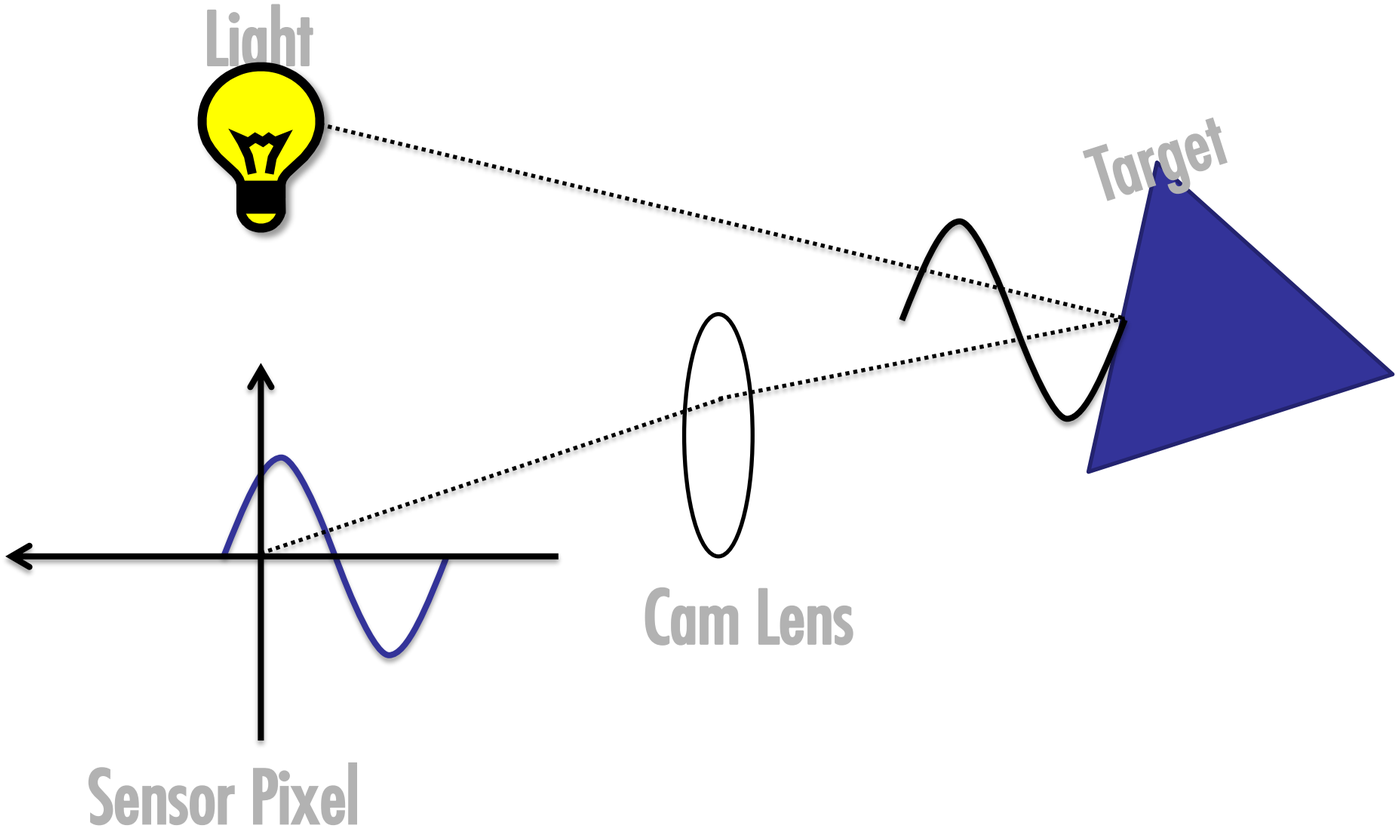


Time of Flight

Working Principle

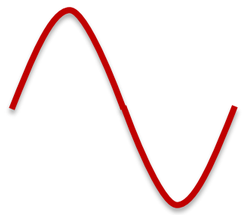


Modulated Signal

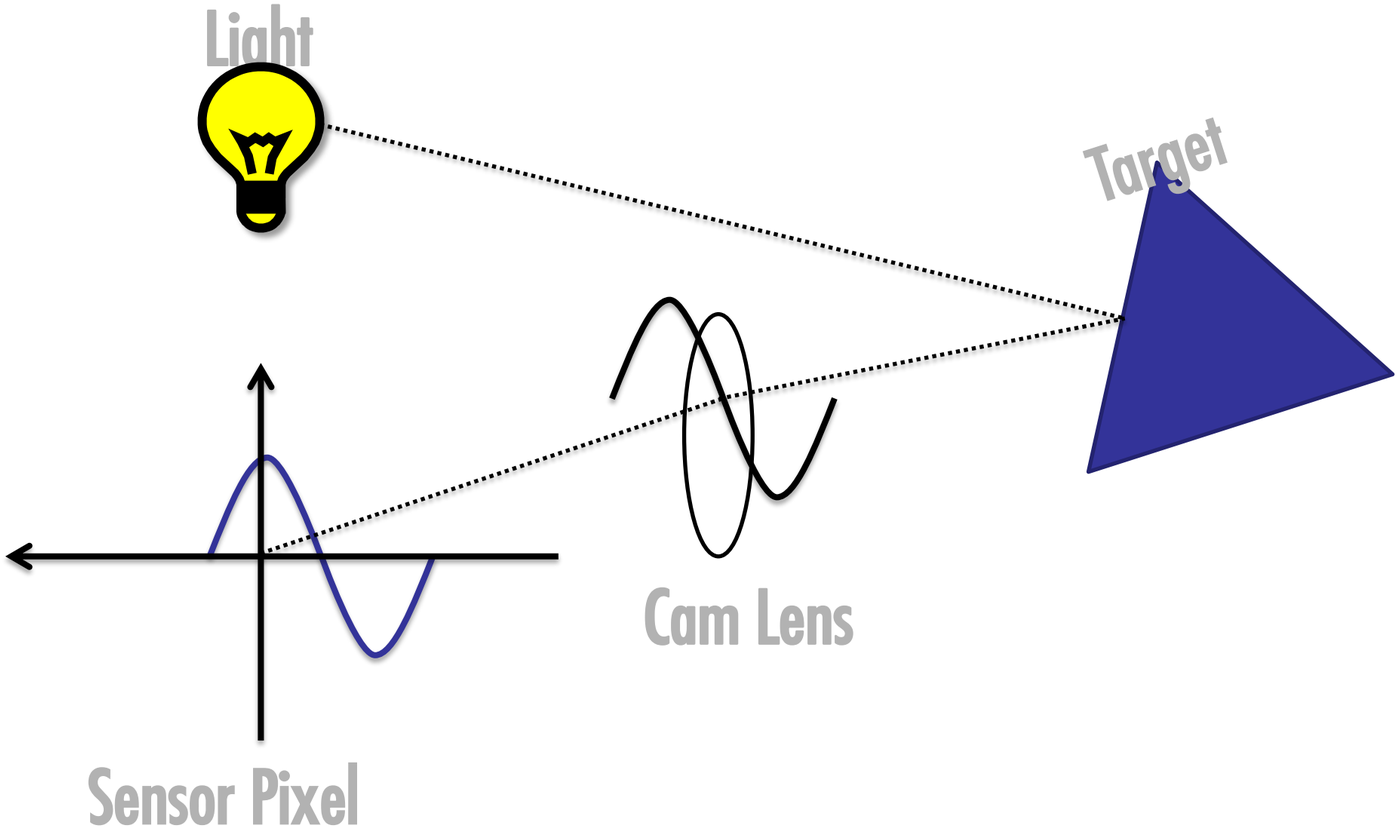


Time of Flight

Working Principle

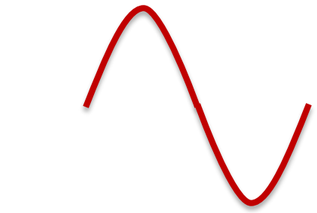


Modulated Signal

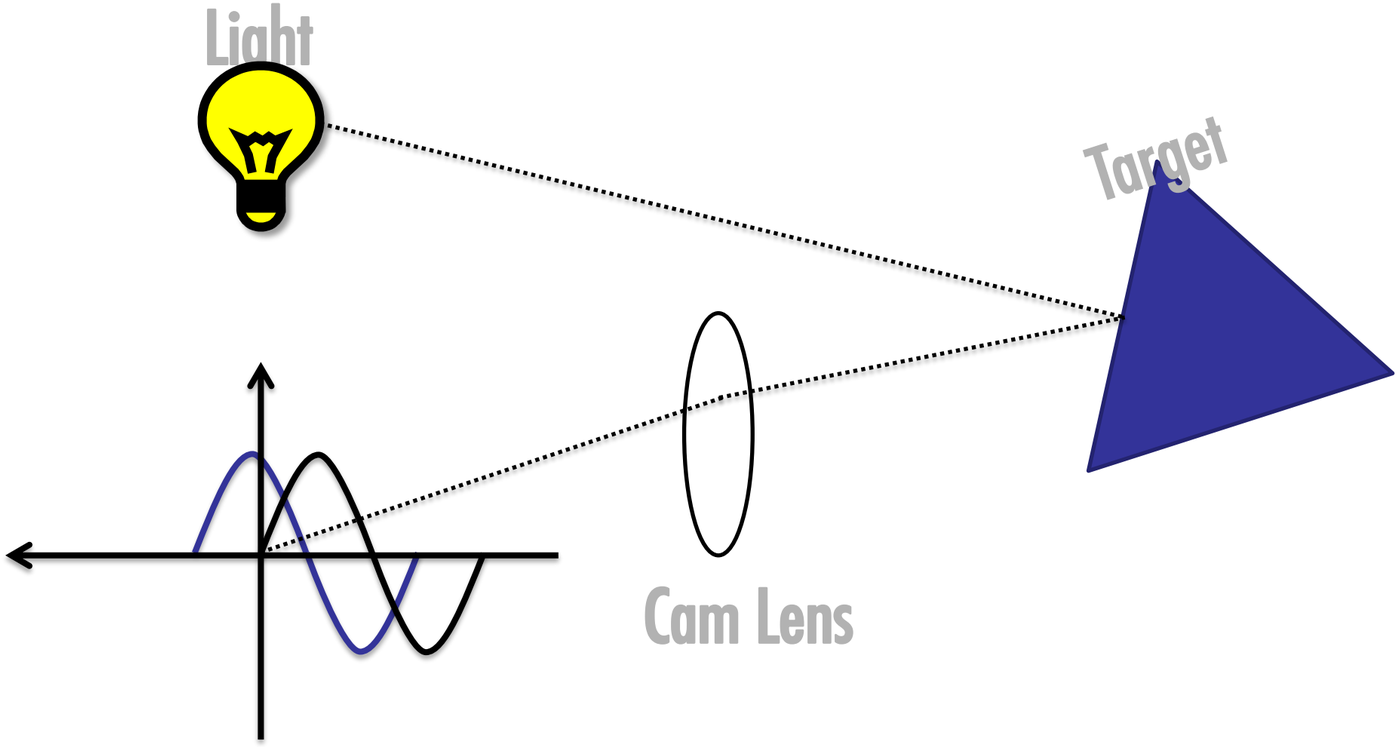


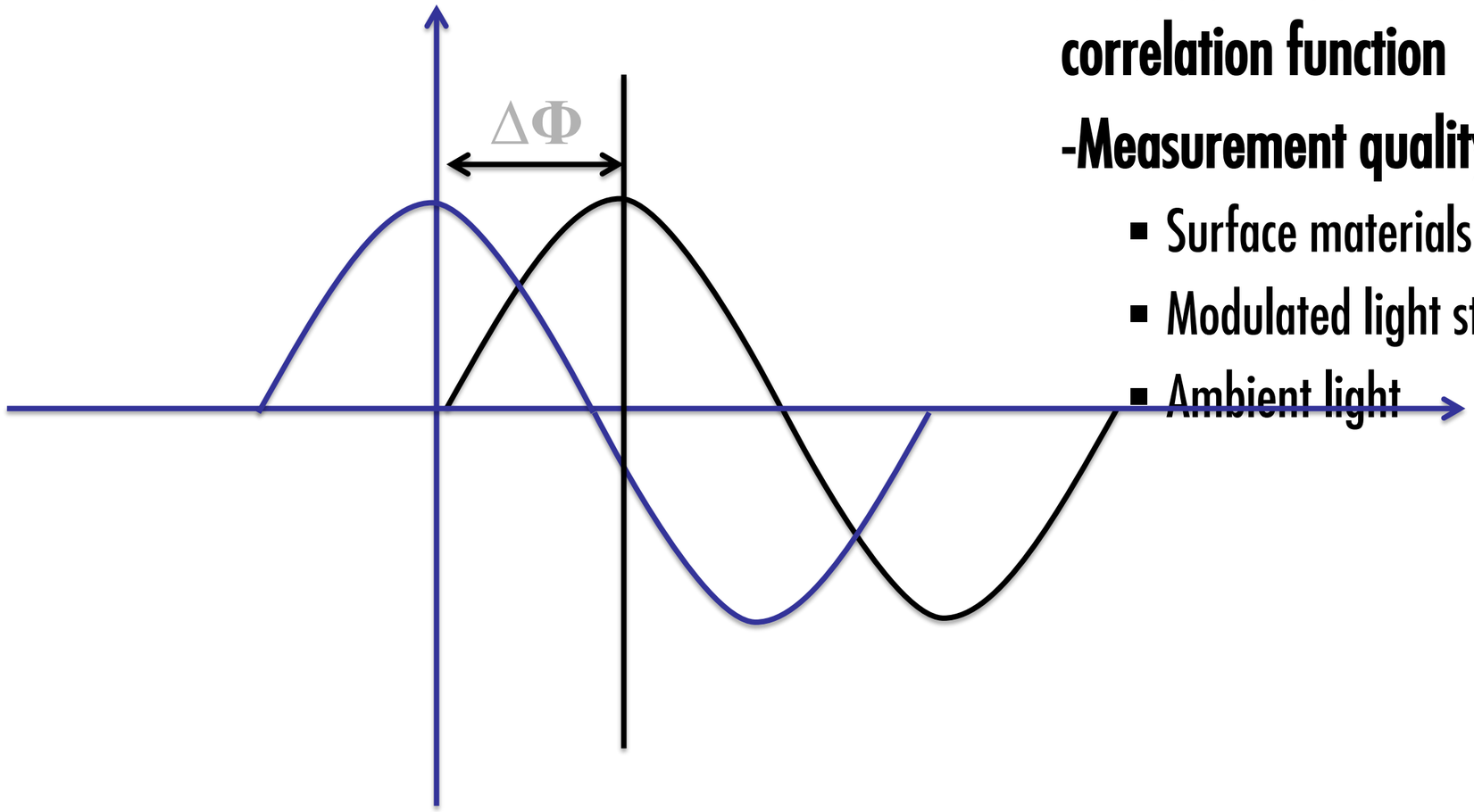
Time of Flight

Working Principle



Modulated Signal





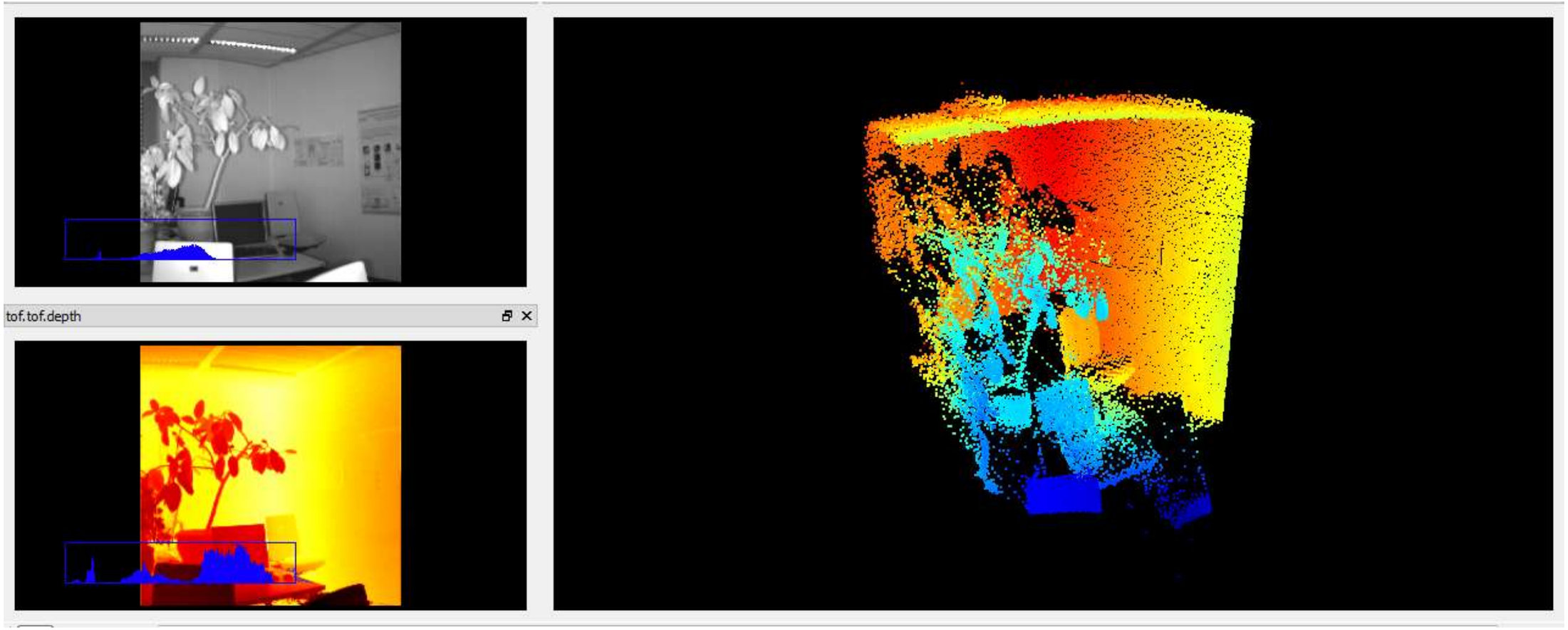
-Phase shift determined by sampling the correlation function

-Measurement quality given by:

- Surface materials
- Modulated light strength
- Ambient light

Tools for the Stereo/post-Processing

Example Data

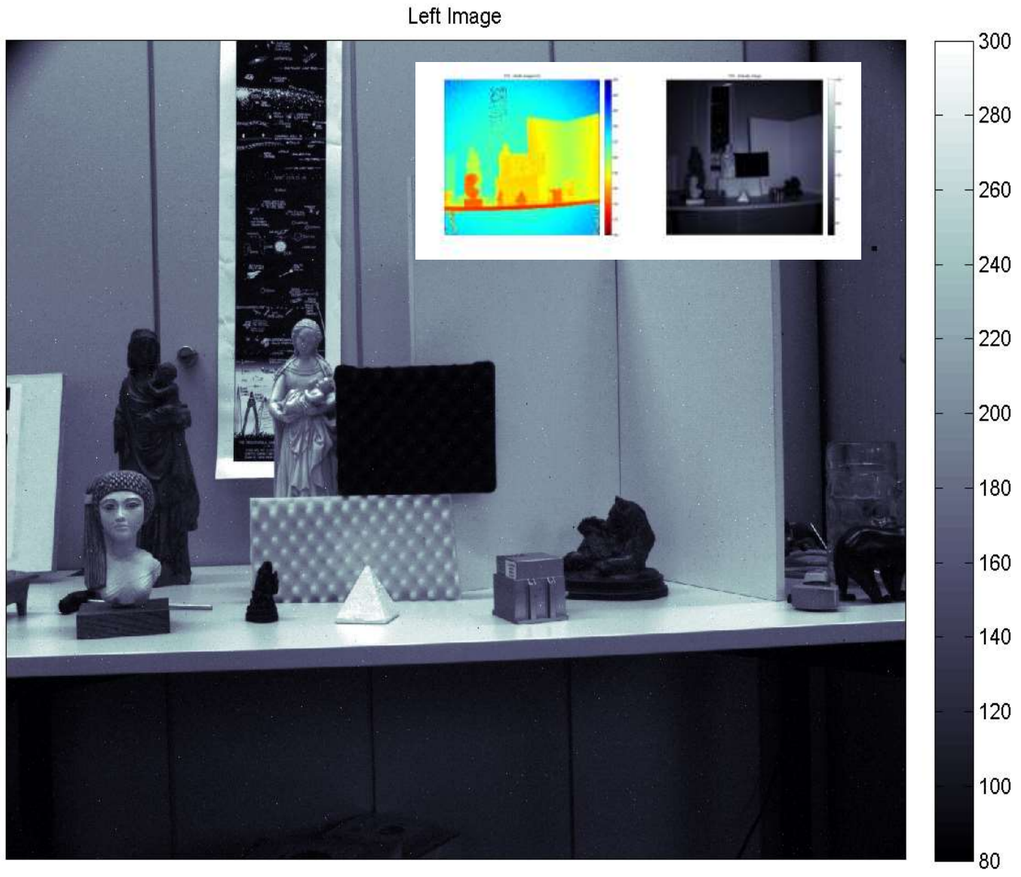


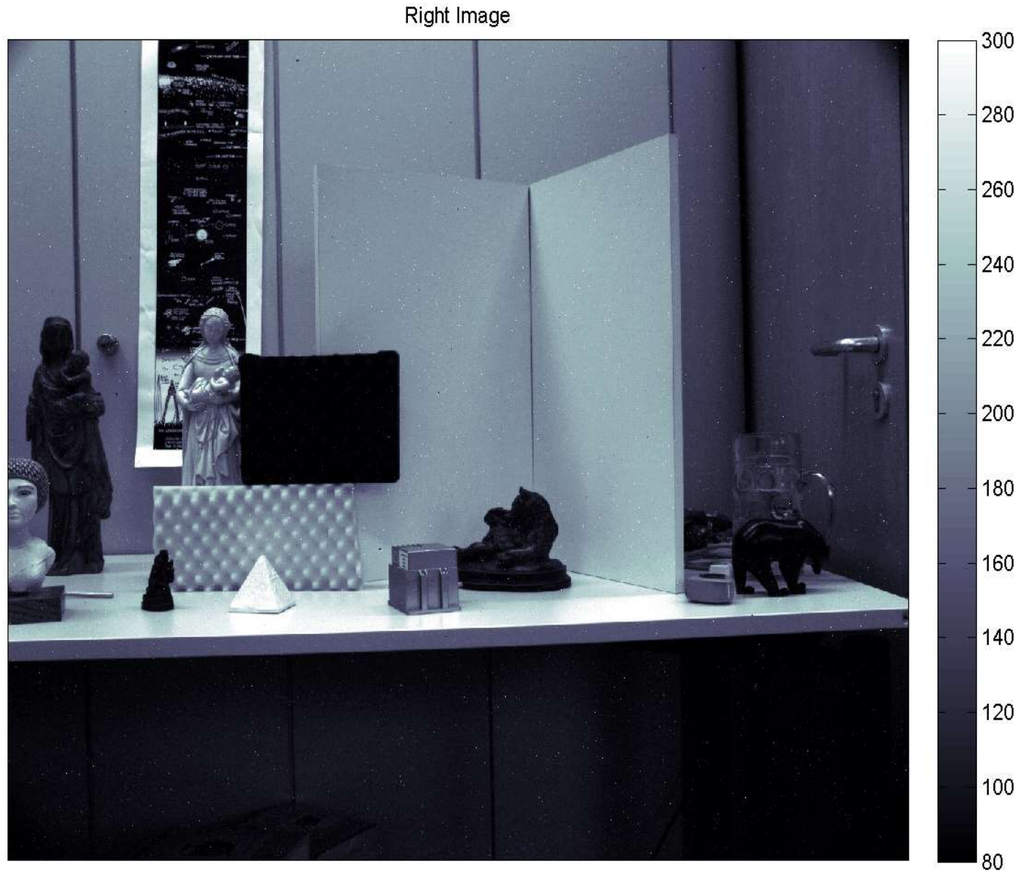
Time of Flight

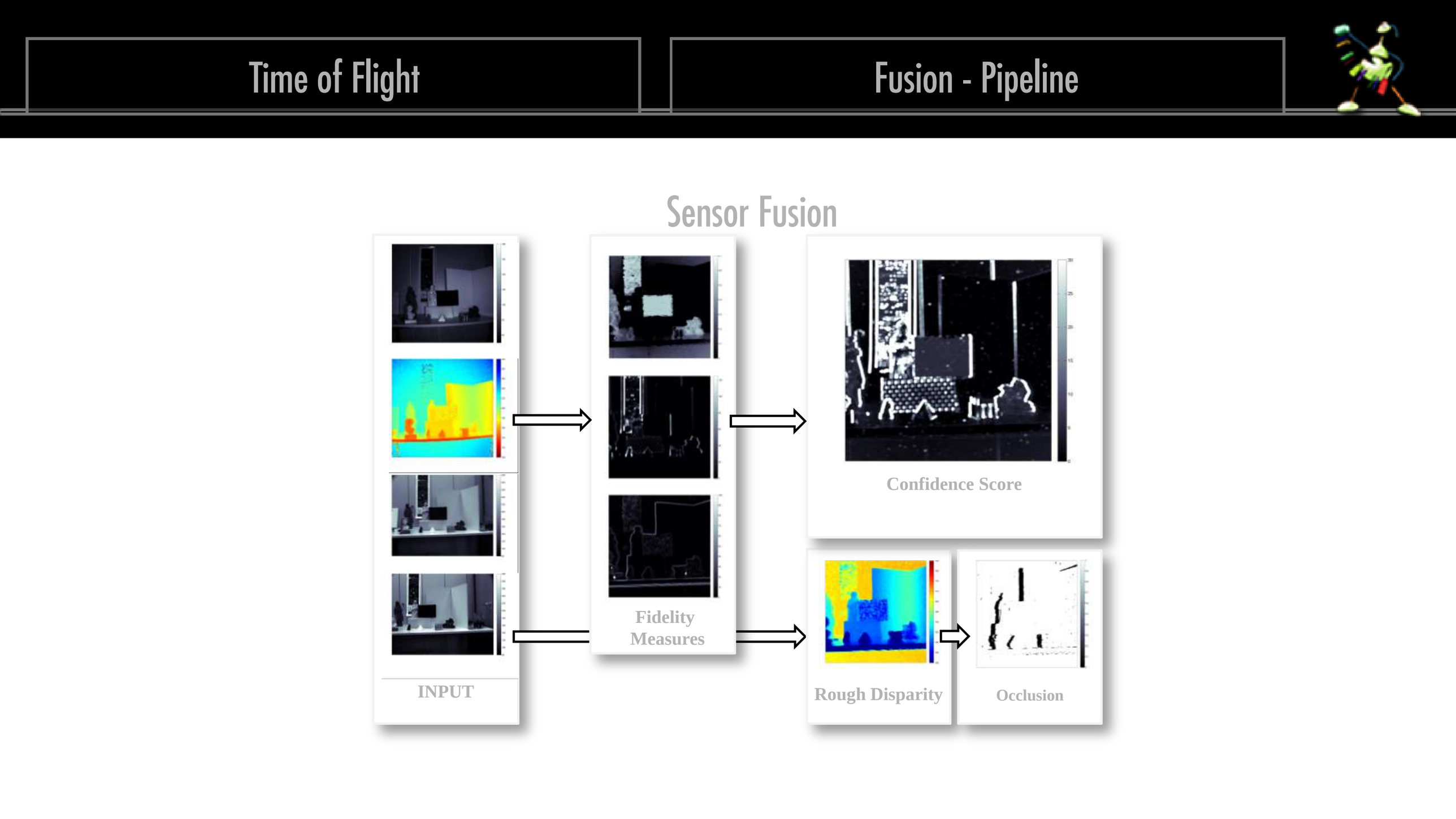
ToF-Stereo Fusion (ECCV Workshops 2012)

Time of Flight

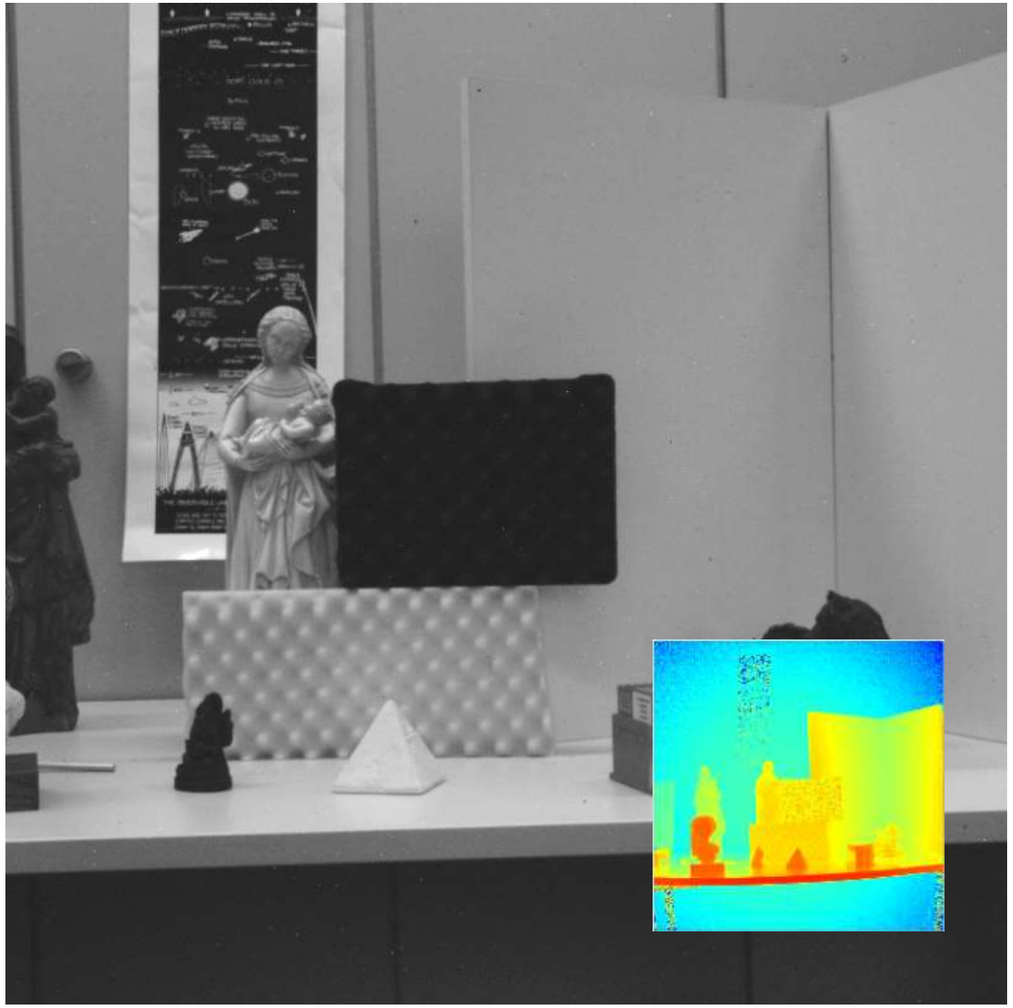
Fusion - Input Data



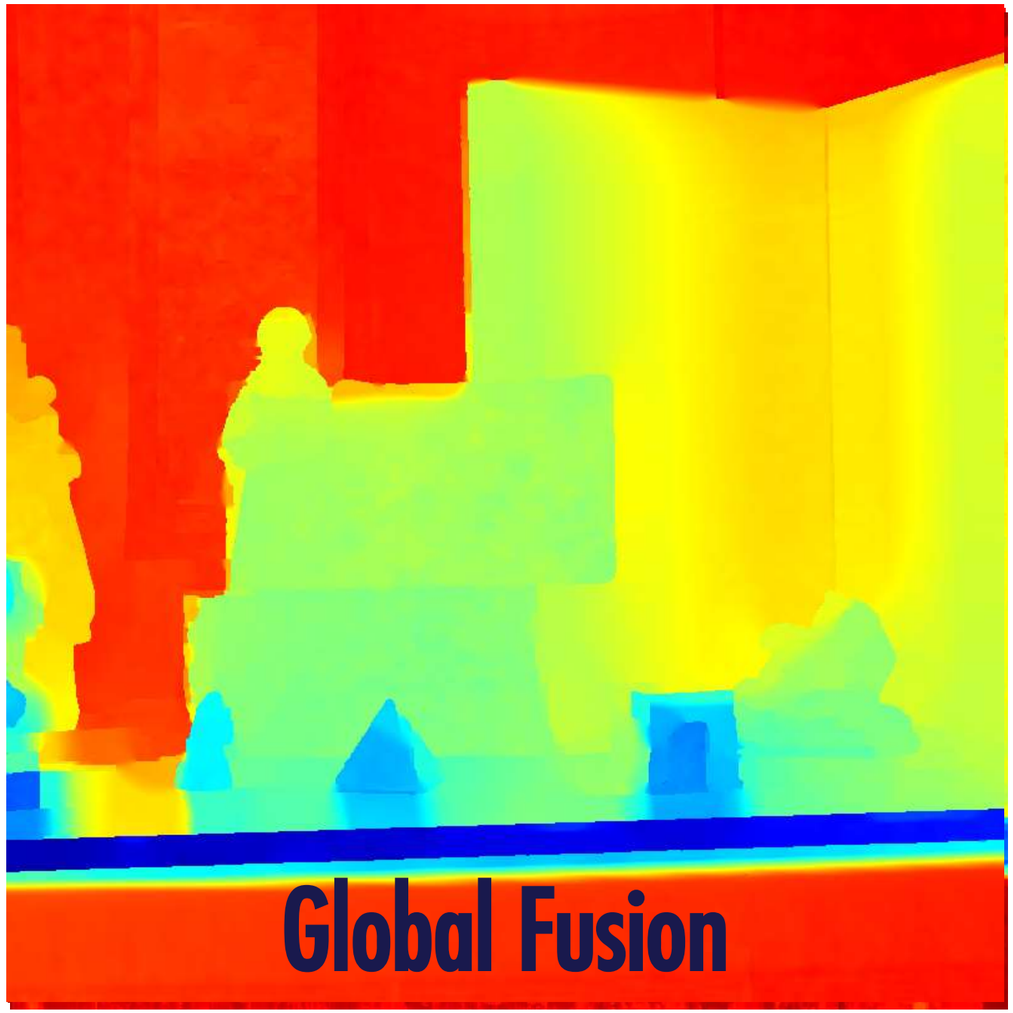



Sensor Fusion
INPUT
Fidelity Measures
Confidence Score
Rough Disparity
Occlusion

Time of Flight



Fusion - Results

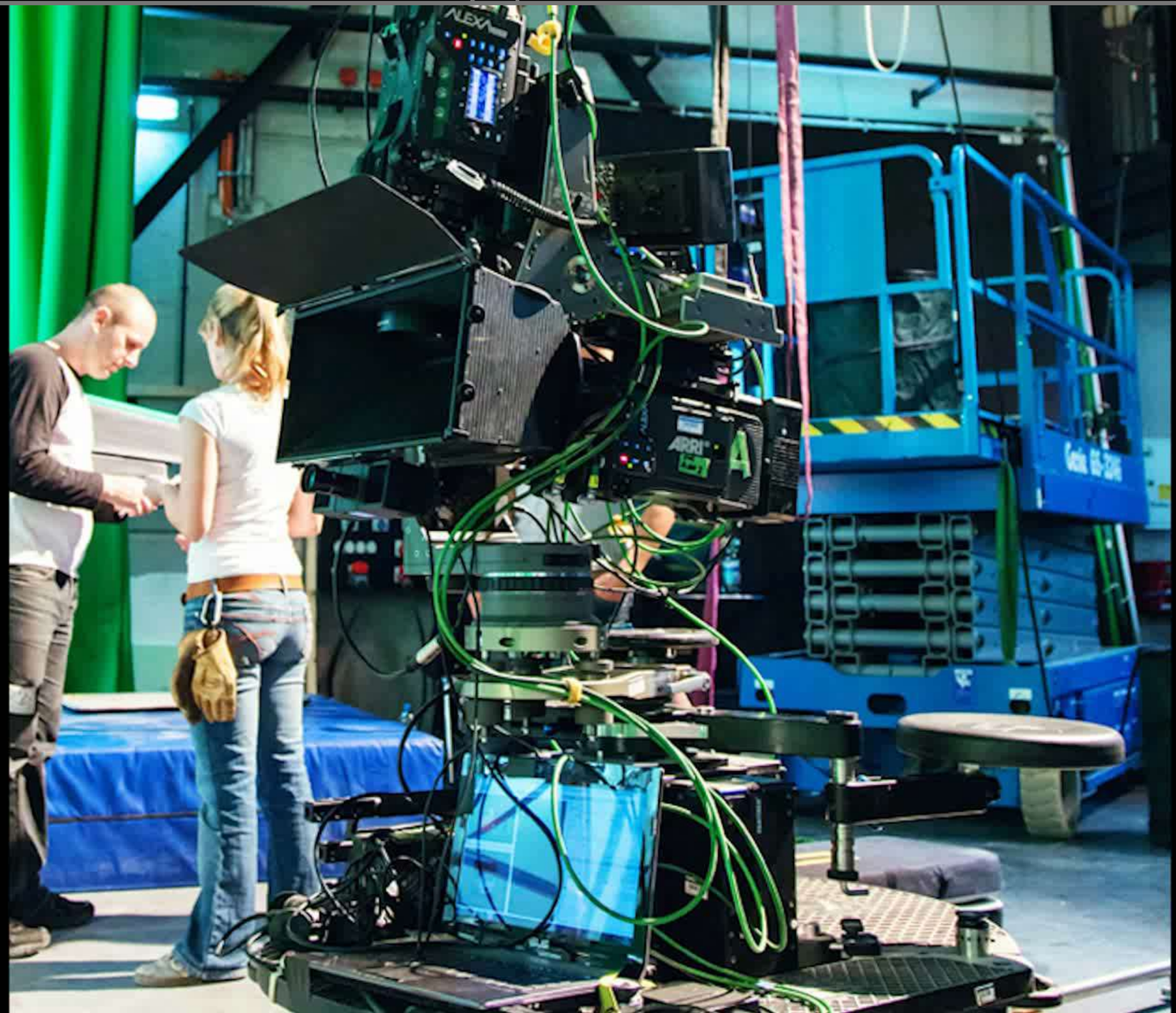


Time of Flight

View Synthesis

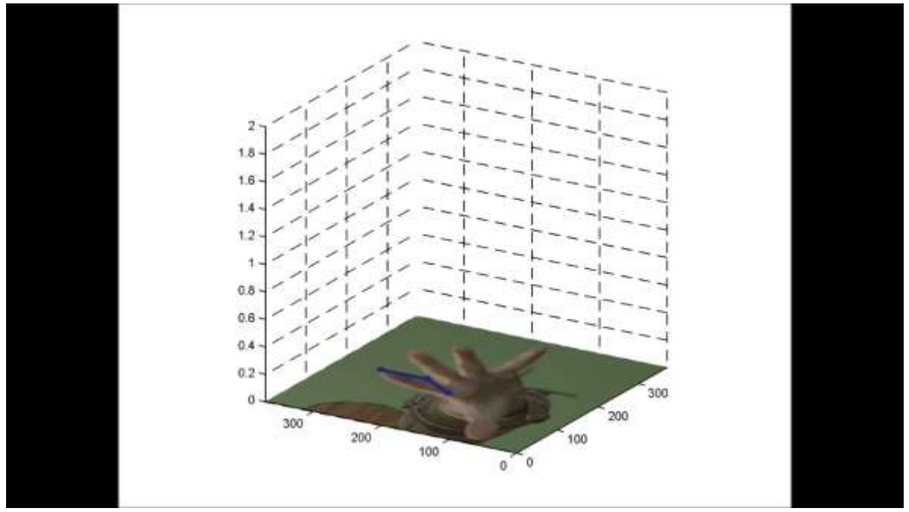
Time of Flight

On Set Tests



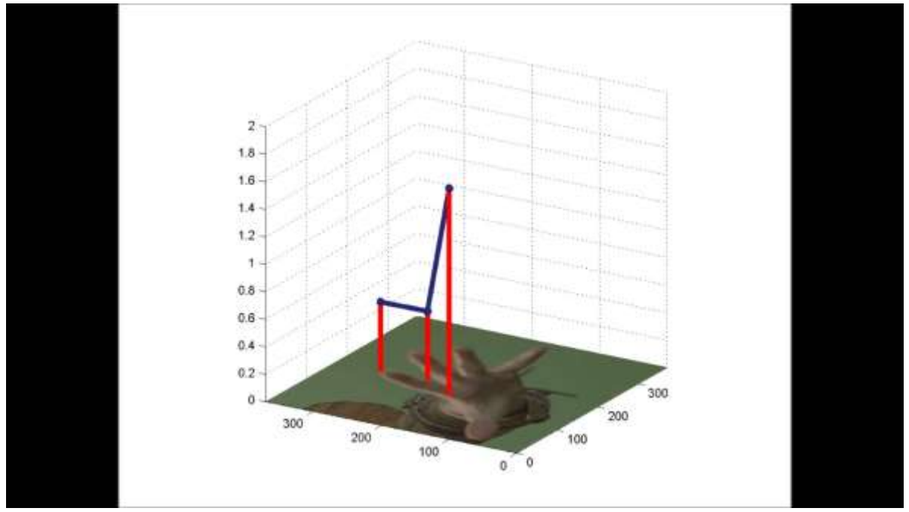
Time of Flight

Conversion Workflow



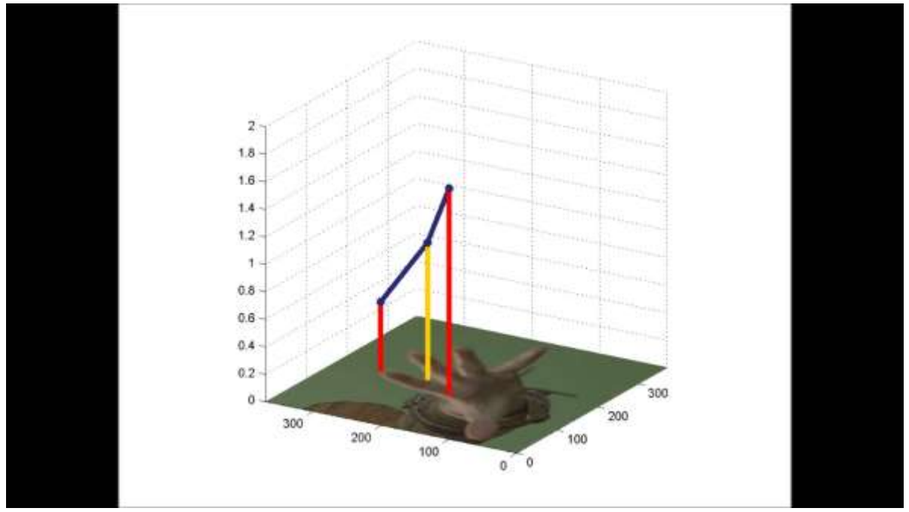
Time of Flight

Conversion Workflow



Time of Flight

Conversion Workflow



Time of Flight

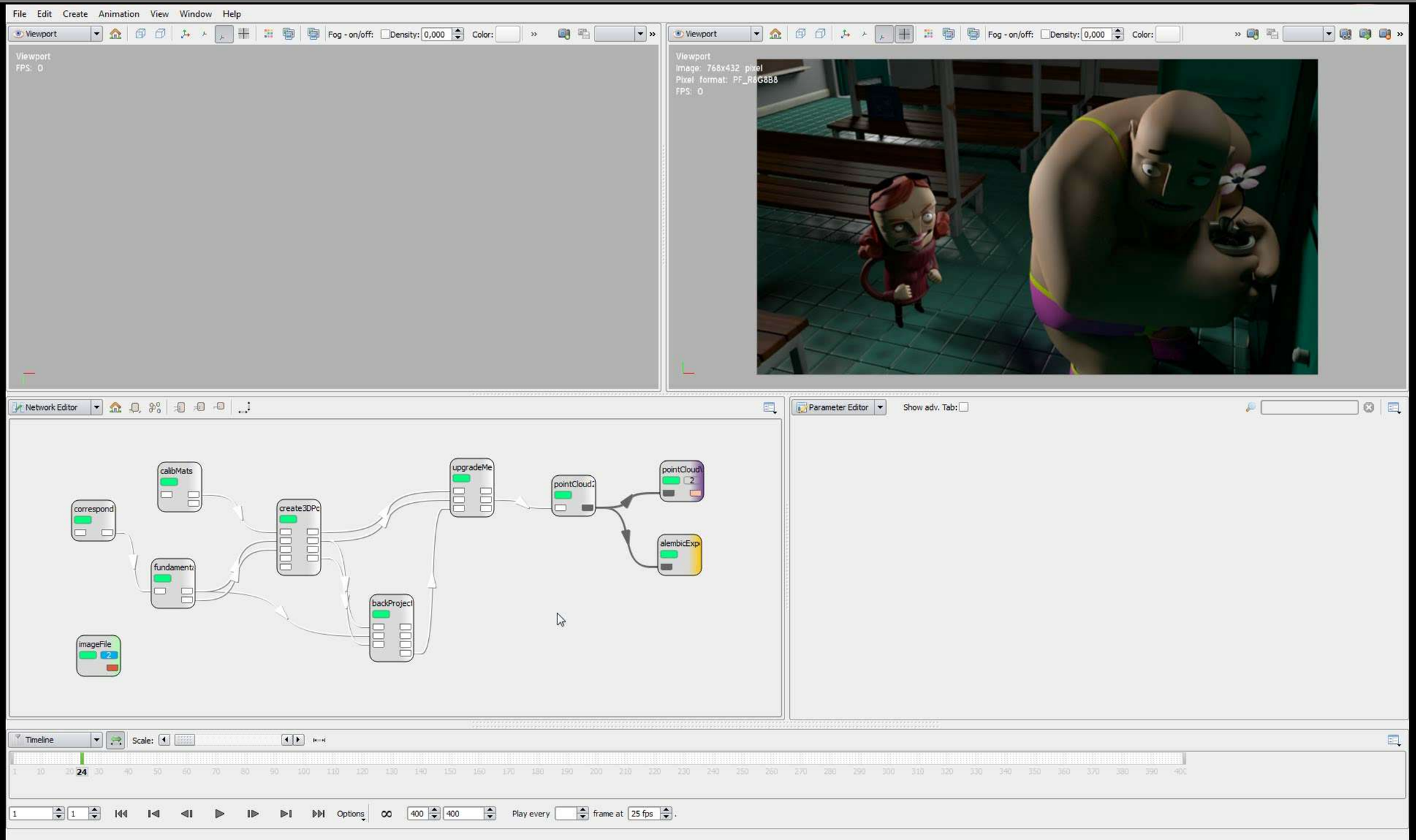
Footage Comparison

DCP: Time Of Flight Conversion (Sq120-DM)

Back to Simon...

Set Reconstruction

Conversion and Export



Institute of Animation

Join us!

- Interns, diploma, bachelor and master thesis
- **Application process for TD open until 3rd of May!**
- Visit our interactive installation at trade floor, **booth 17**!

http://research.animationsinstitut.de

http://hci.iwr.uni-heidelberg.de

People

Volker Helzle
volker.helzle@filmakademie.de

Simon Spielmann
simon.spielmann@filmakademie.de

Michael Bußler
michael.bussler@filmakademie.de

Thank you!

Daniel Kondermann
daniel.kondermann@iwr.uni-heidelberg.de

Rahul Nair
rahul.nair@iwr.uni-heidelberg.de

Moritz Becker
moritz.becker@iwr.uni-heidelberg.de

Michael Baron
michael.baron@iwr.uni-heidelberg.de