Variational Methods for Computer Vision

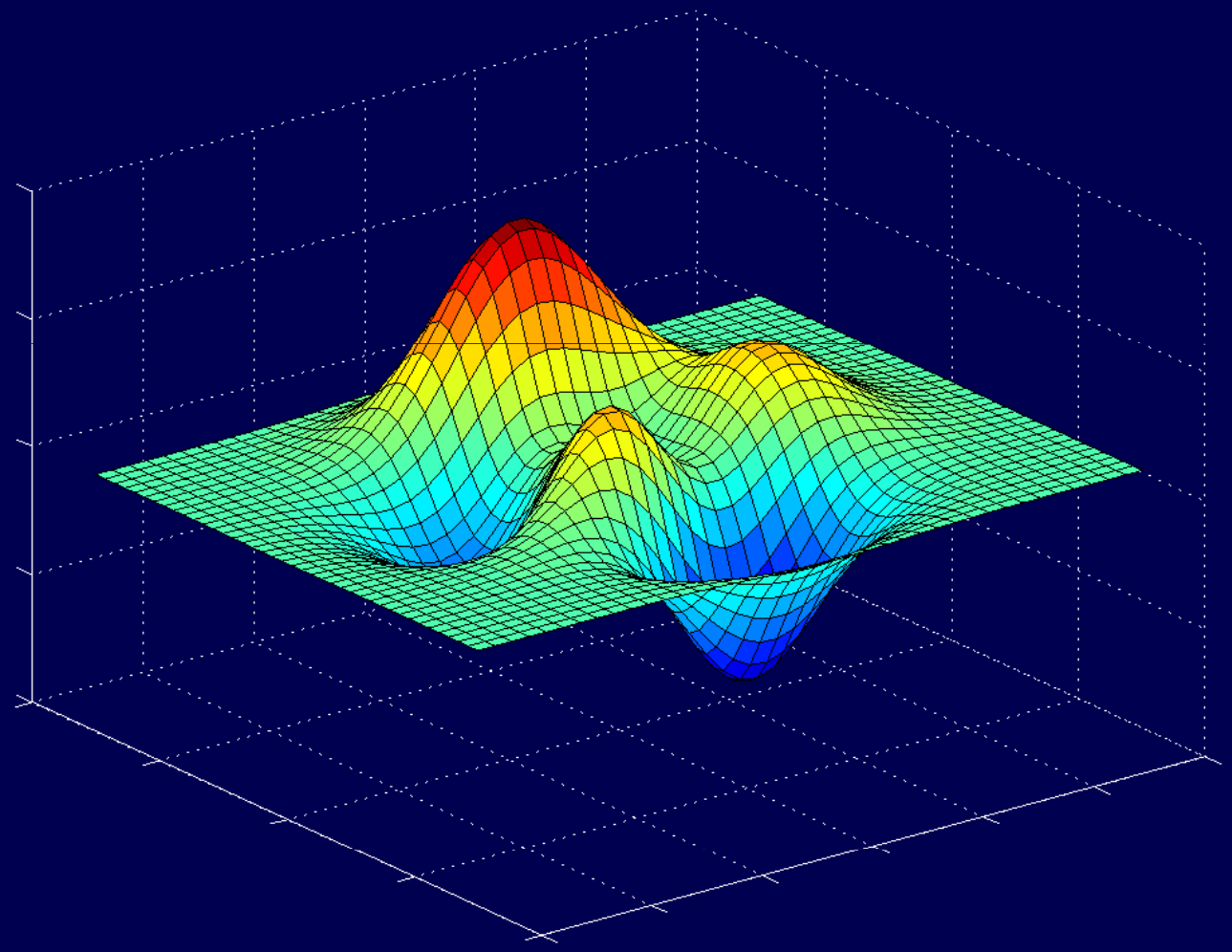
Prof. Dr. Daniel Cremers
Chair for Computer Vision
Computer Science Department, TUM

Exercises: Dipl.-Inf. Mohamed Souiai

Motivation:
Why Variational Methods?

Geometric Reconstruction

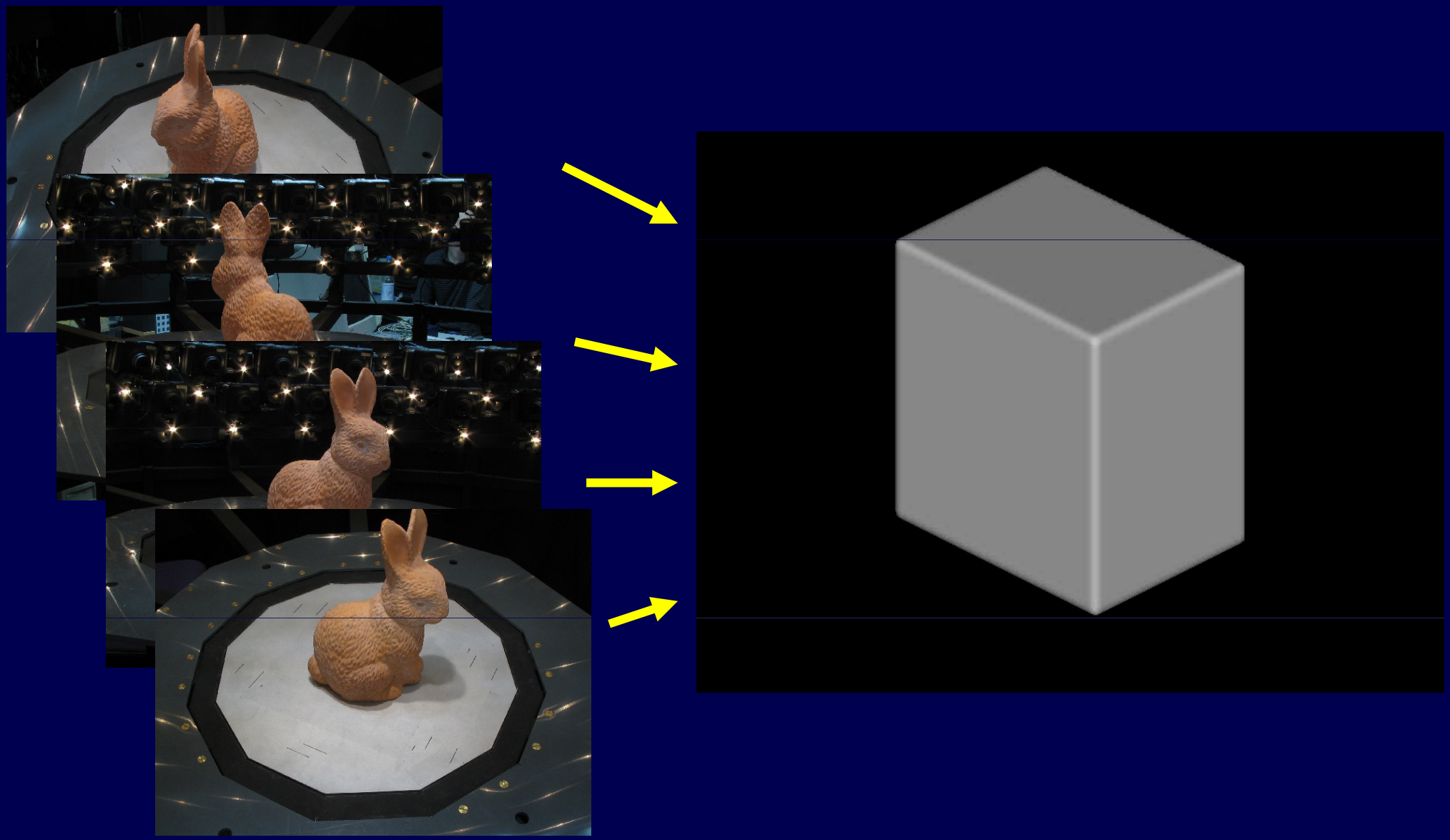
Solutions via Energy Minimization



Two research challenges:

1. Construct appropriate energies
2. Compute their minimizers

Evolution to Minimum Energy

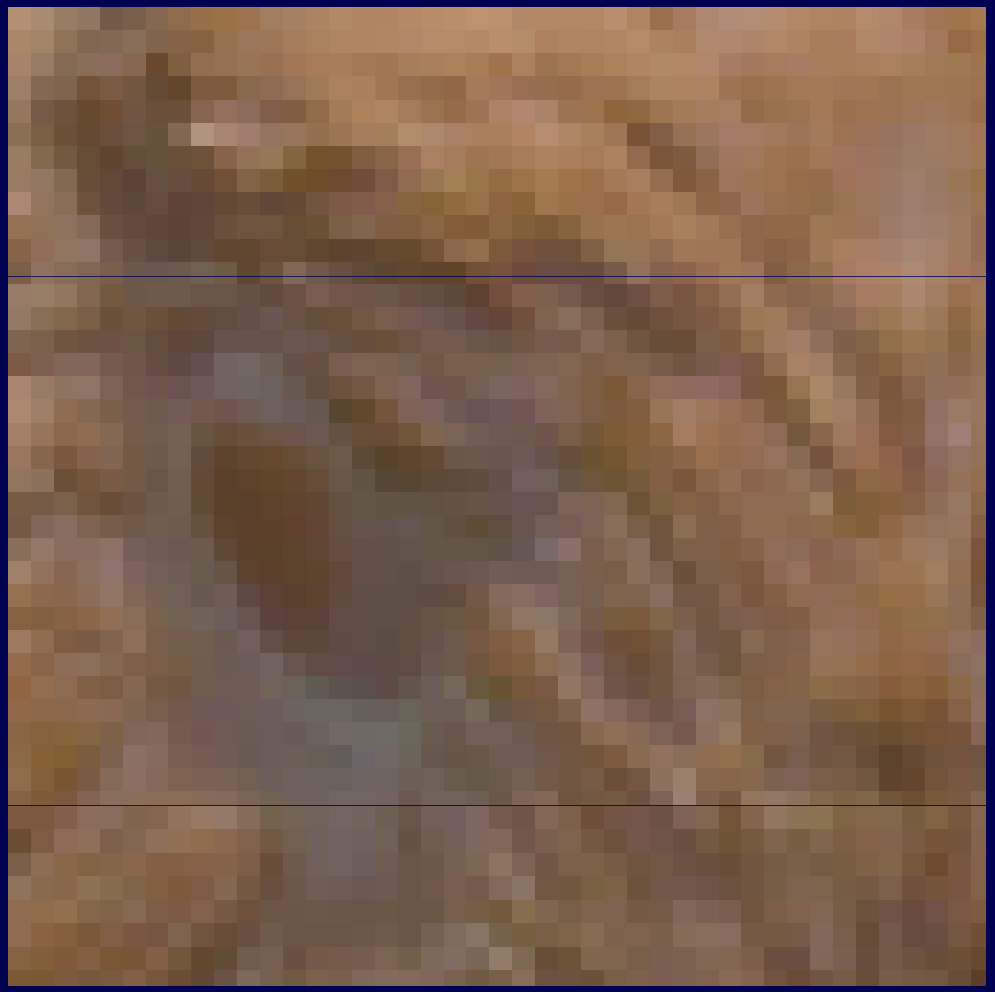


Kolev et al., Int. J. of Computer Vision 2009

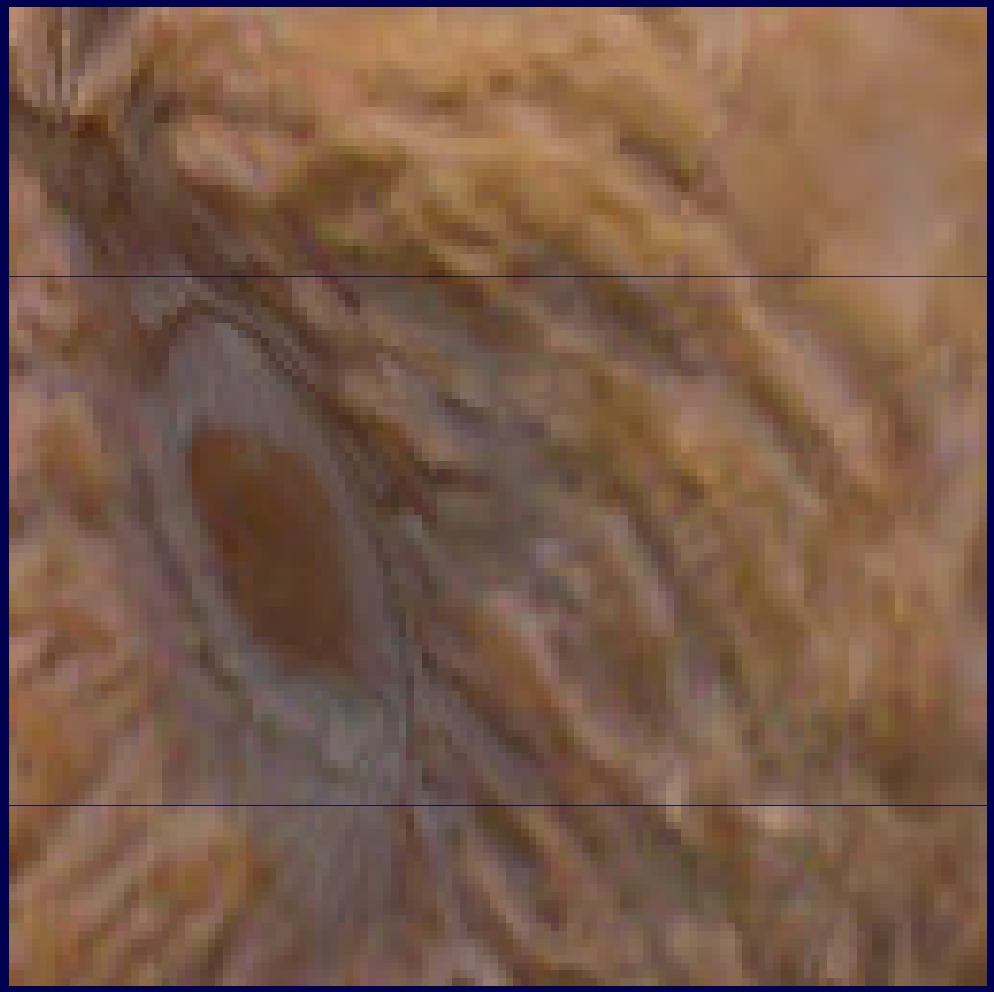
Multiview Superresolution

Goldlücke, Cremers, ICCV '09, DAGM '09

Multiview Superresolution



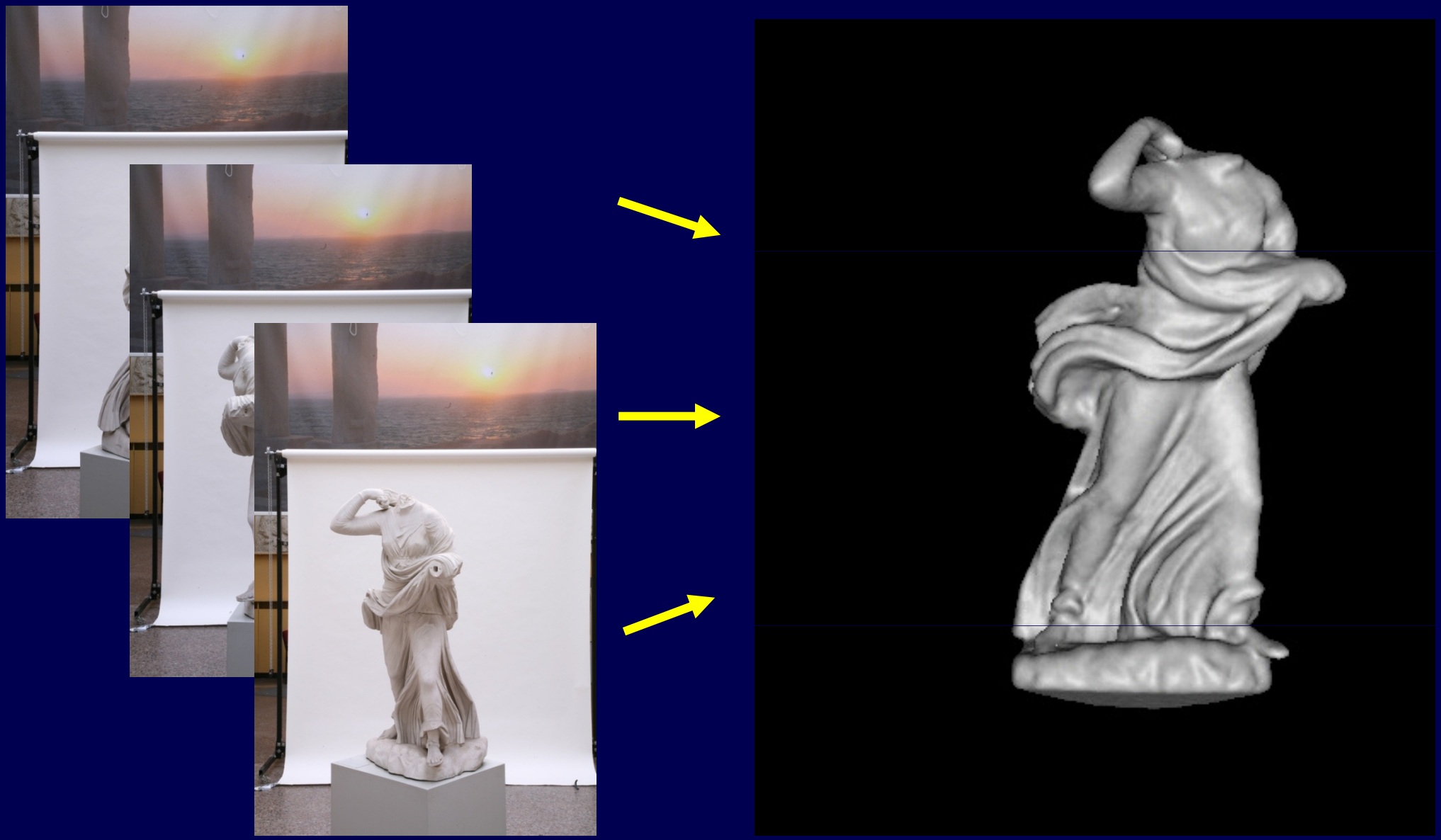
Closeup of input image



Super-resolution texture

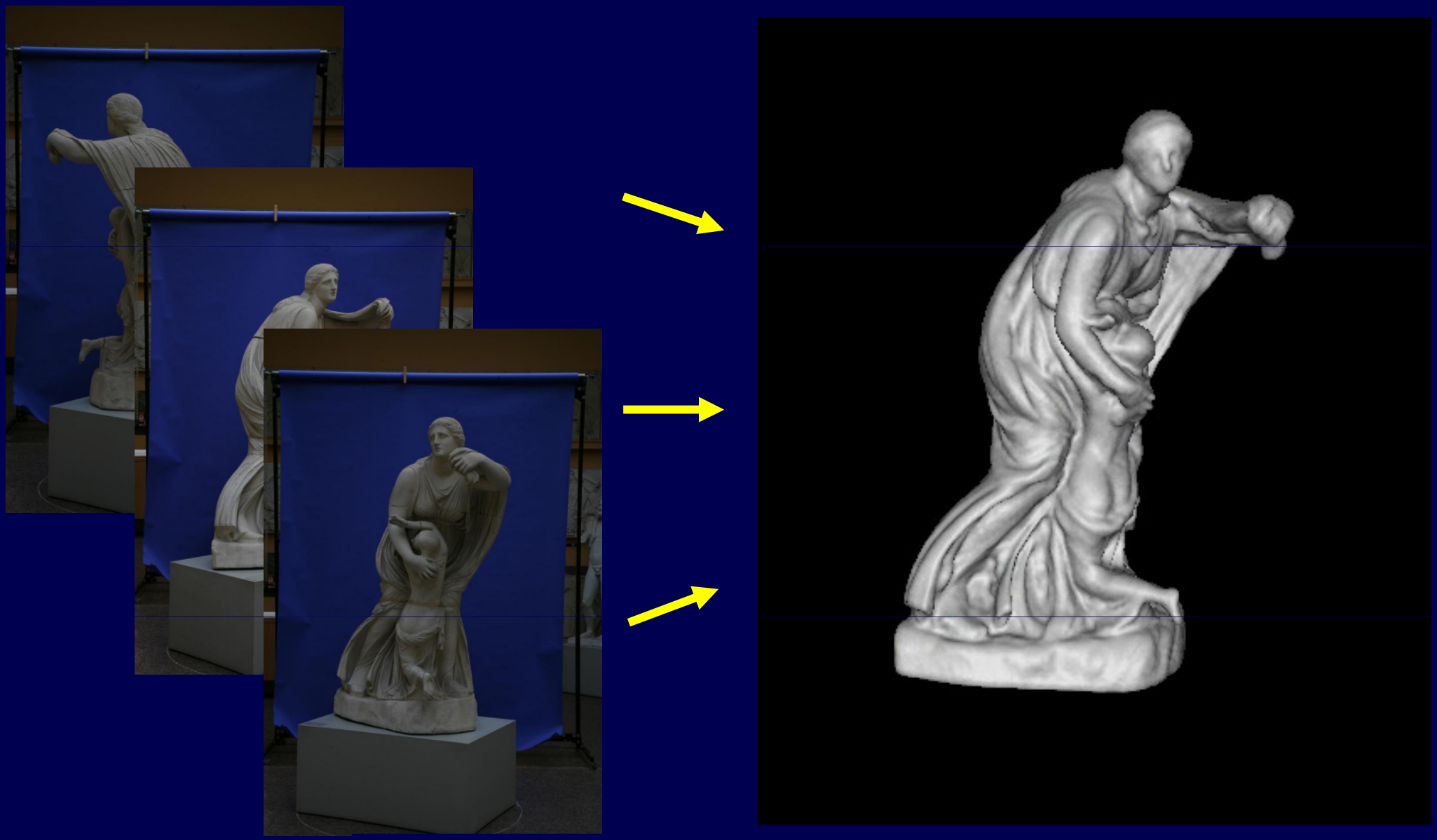
Goldlücke, Cremers, ICCV '09, DAGM '09

Reconstructing the Niobids statues



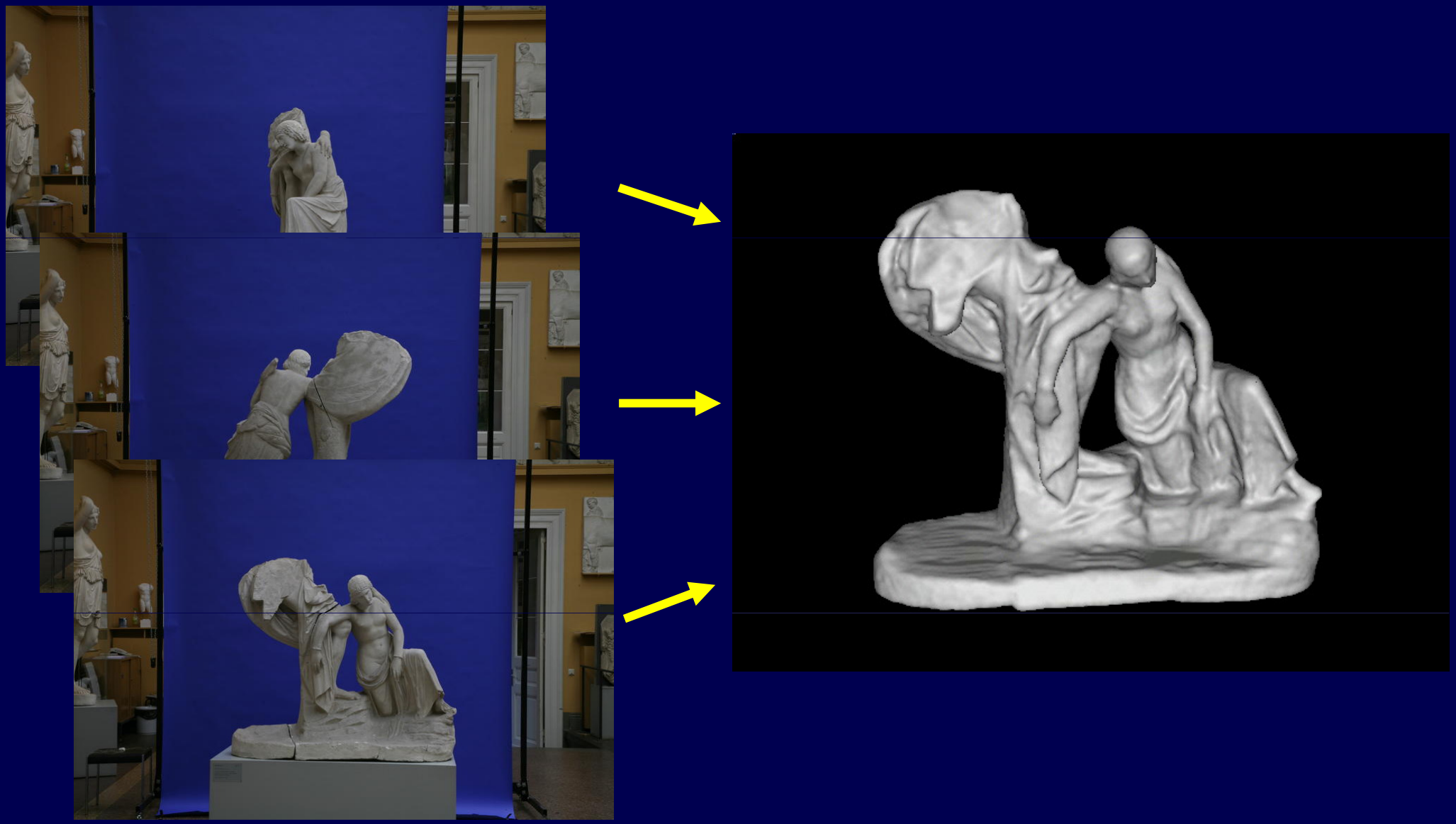
Kolev, Cremers, ECCV '08, PAMI 2010

Reconstructing the Niobids statues



Kolev, Cremers, ECCV '08, PAMI 2010

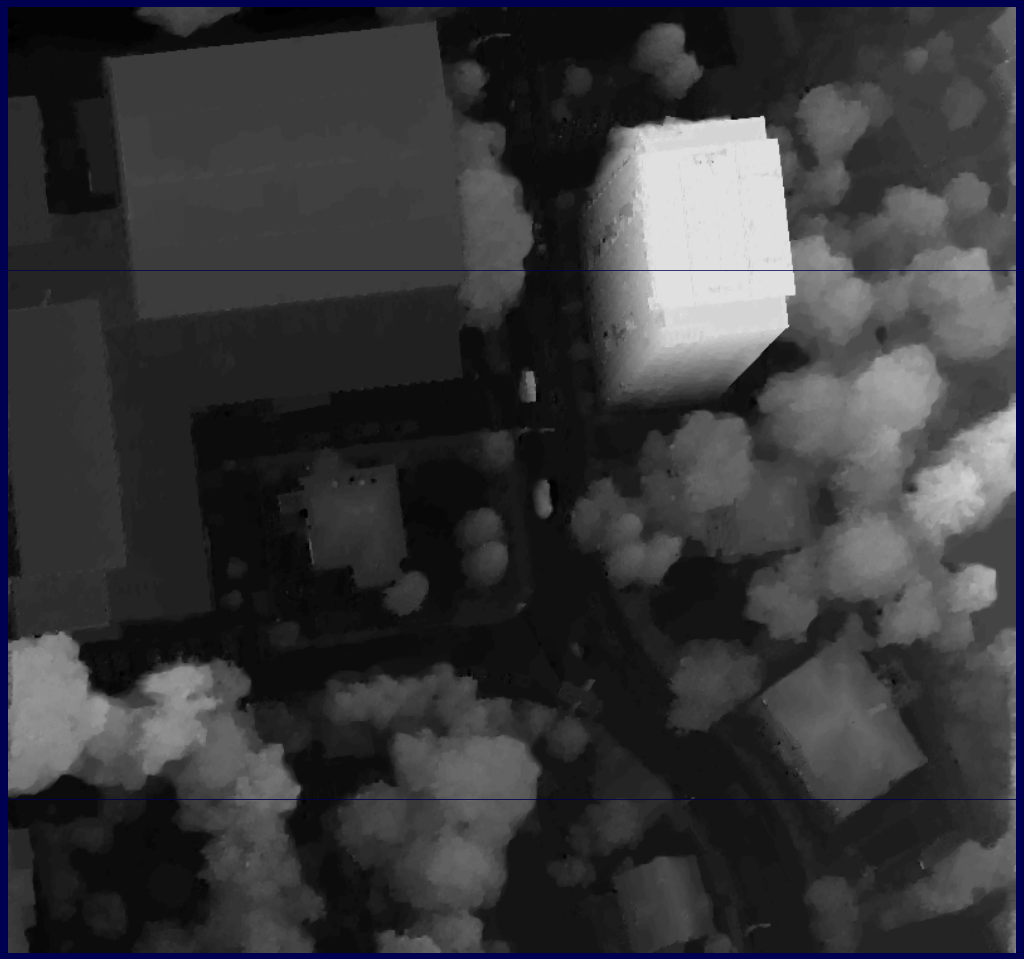
Reconstructing the Niobids statues



Kolev, Cremers, ECCV '08, PAMI 2010

Stereo Depth Reconstruction

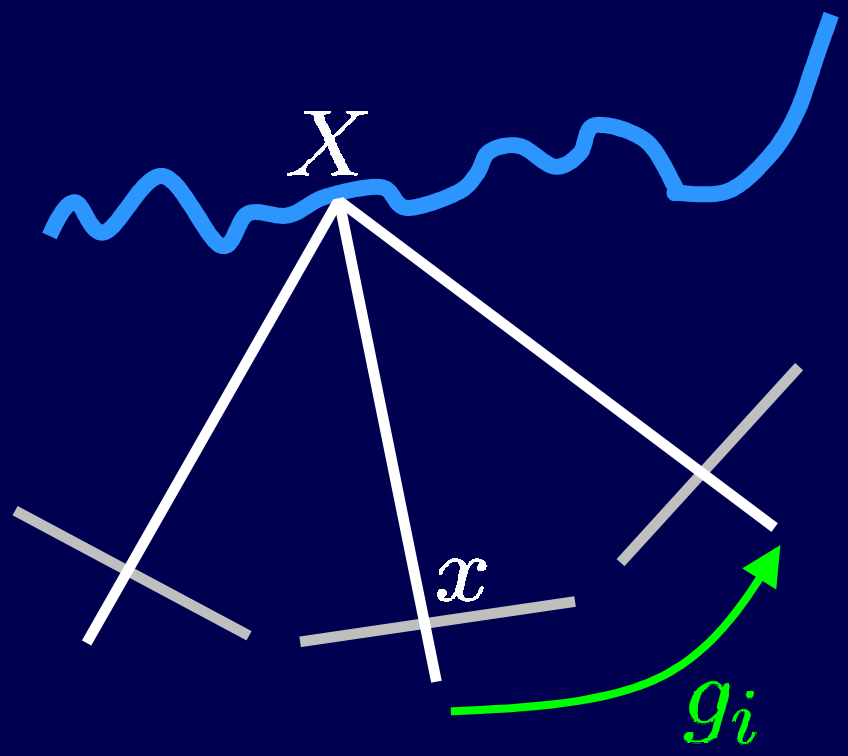
One of two input images



Depth reconstruction

Pock, Schoenemann, Graber, Bischof, Cremers, ECCV '08

Dense geometry from hand-held camera

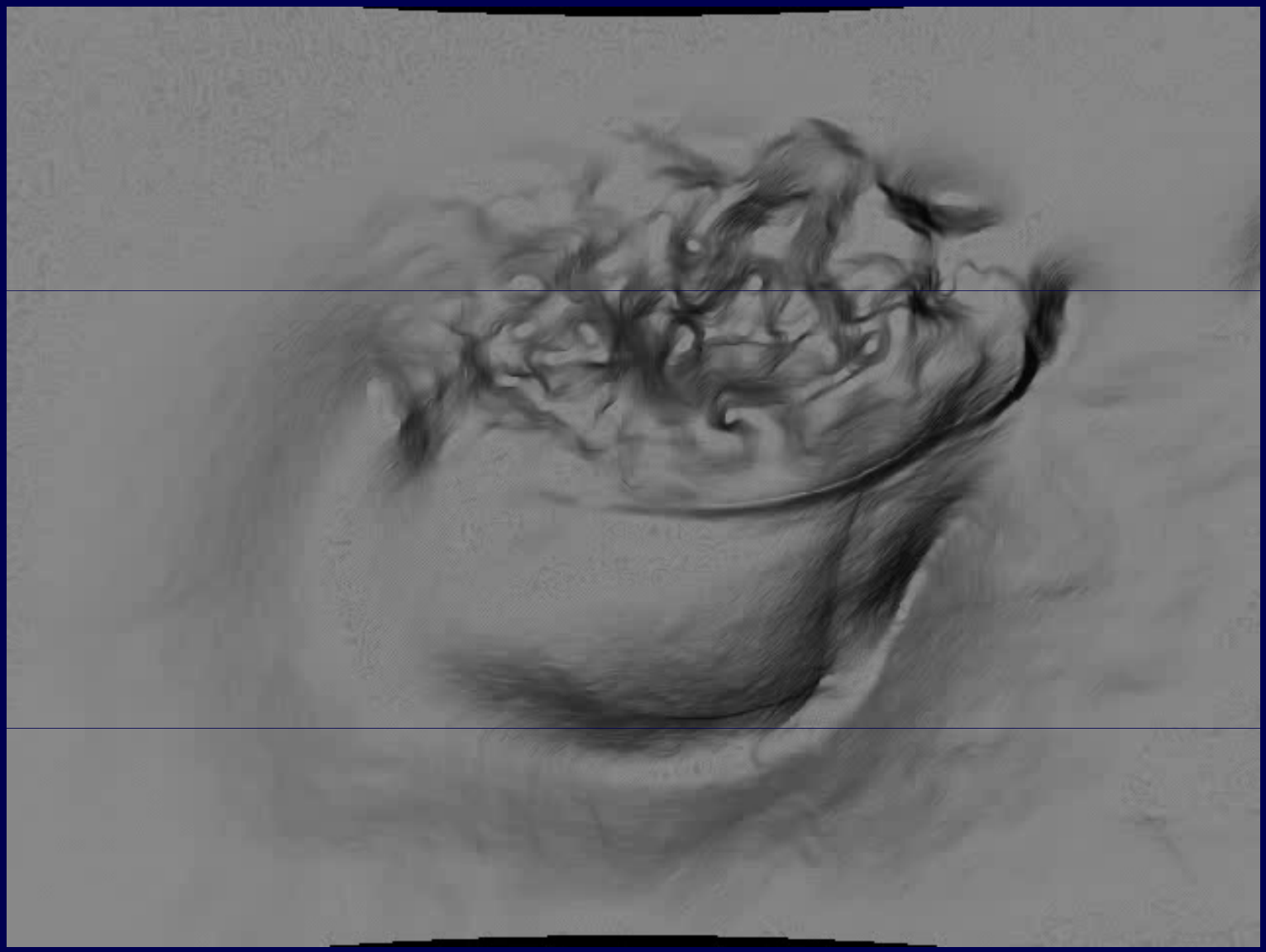


Stuehmer, Cremers, DAGM '10

Dense geometry from hand-held camera

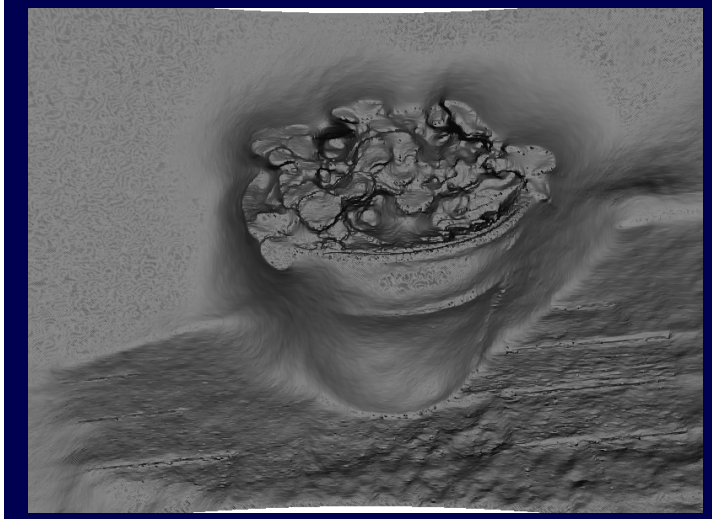
Stuehmer , Gumhold, Cremers, DAGM '10

Dense geometry from hand-held camera

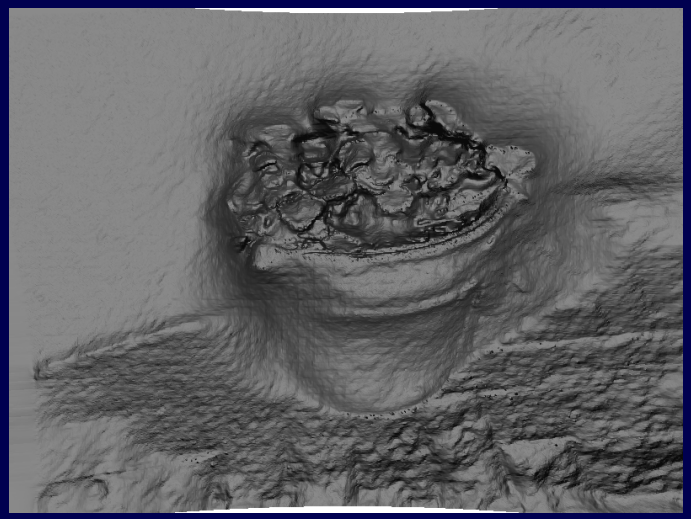


Stuehmer , Gumhold, Cremers, DAGM '10

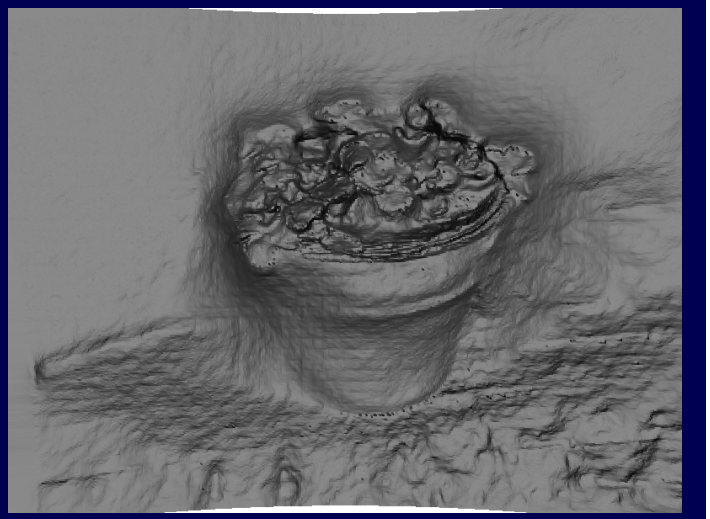
Dense geometry from hand-held camera



1.8 fps



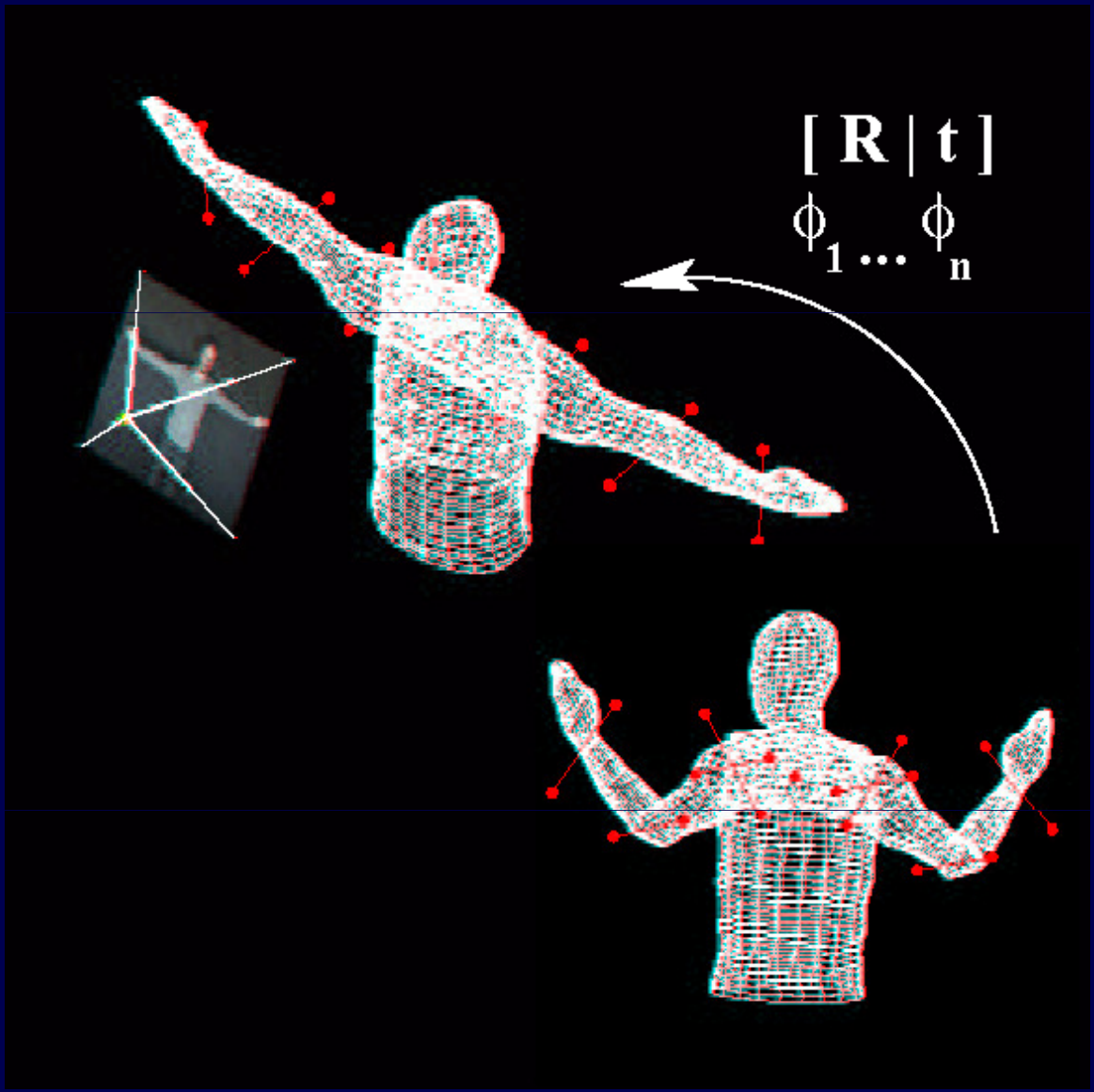
11.3 fps



24 fps

Stuehmer , Gumhold, Cremers, DAGM '10

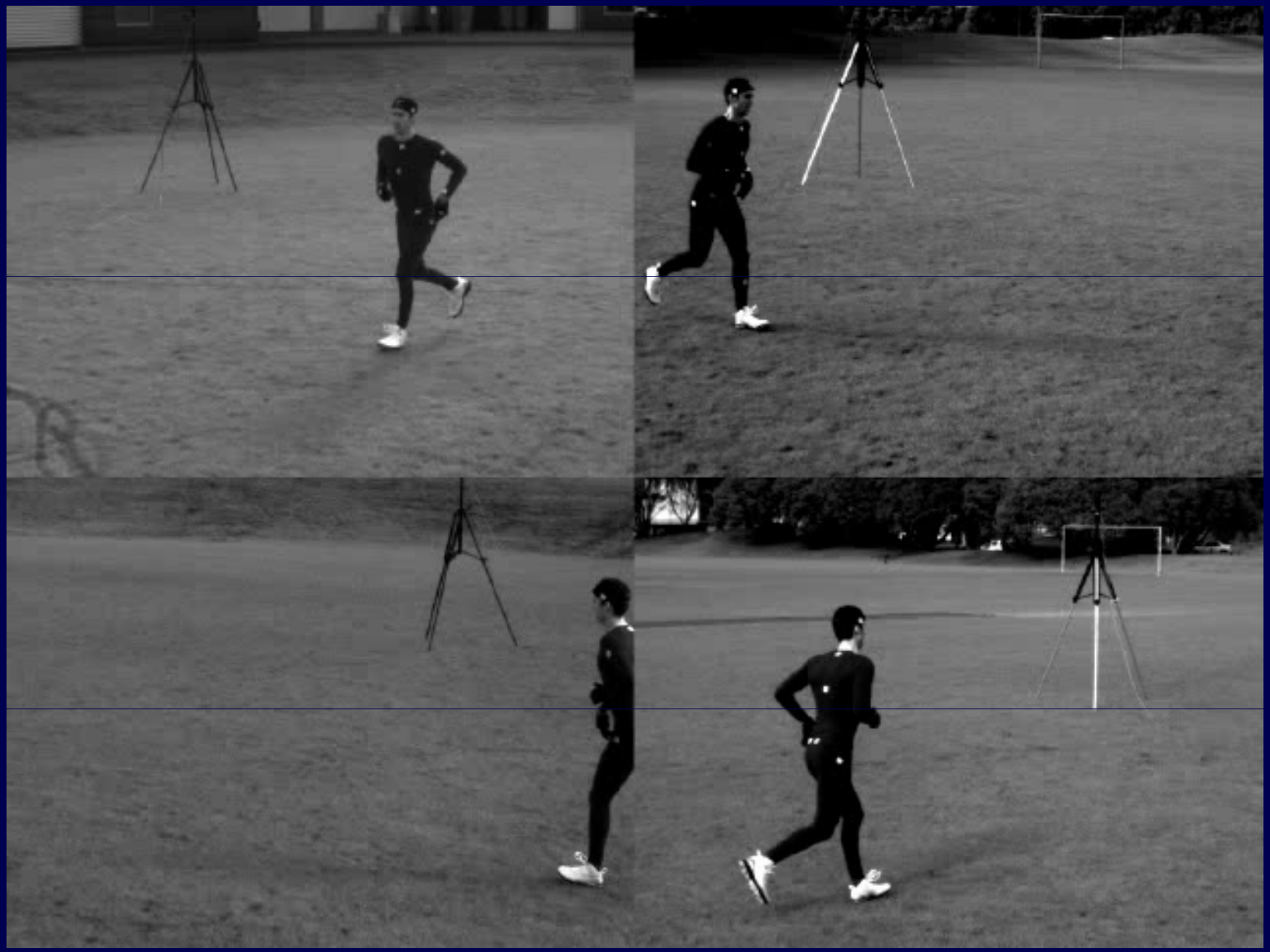
Markerless Motion Capture



Brox, Rosenhahn, Gall, Cremers, PAMI '09

Markerless Motion Capture

Markerless Motion Capture

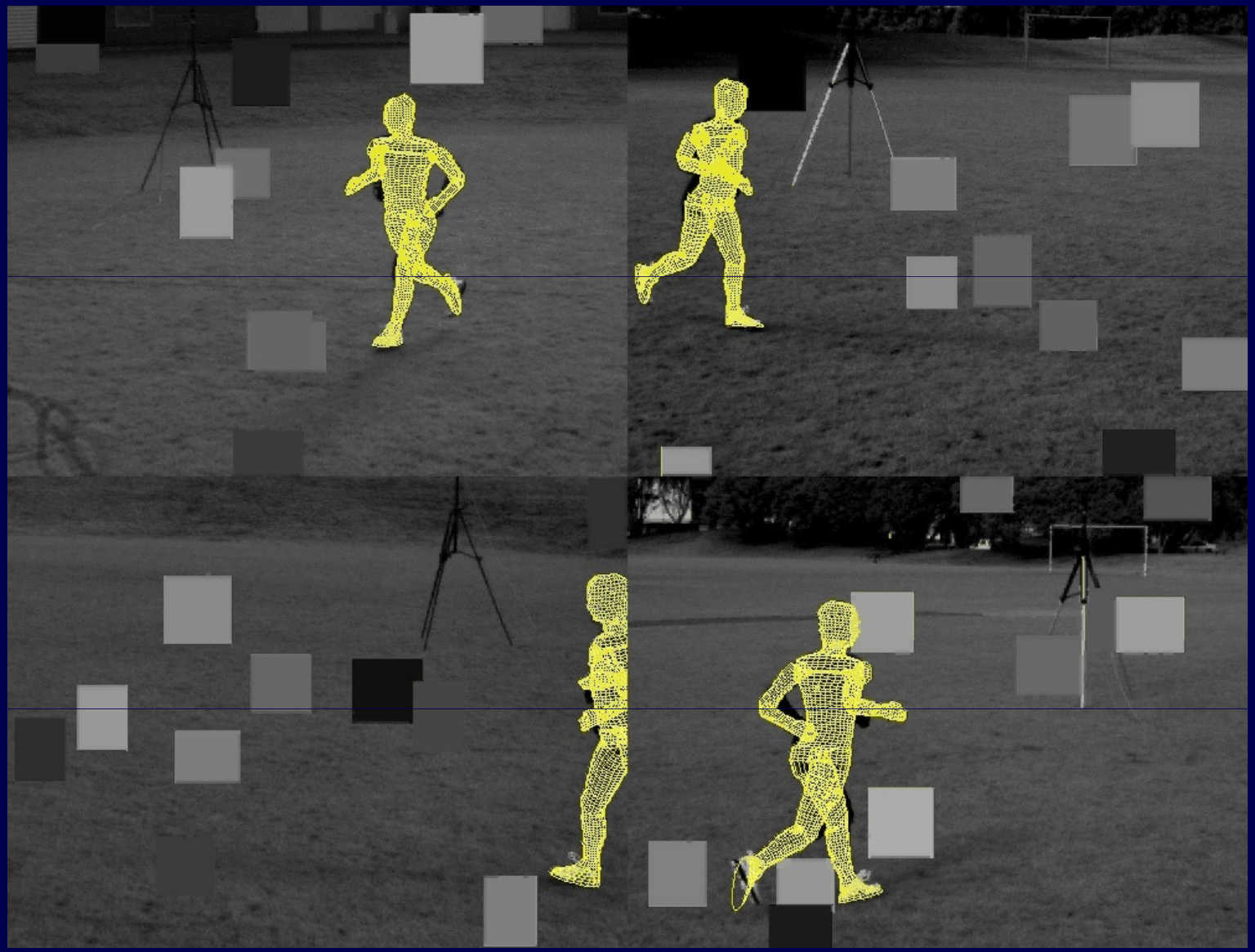


Brox, Rosenhahn, Gall, Cremers, PAMI '09

Markerless Motion Capture

Brox, Rosenhahn, Gall, Cremers, PAMI '09

Markerless Motion Capture

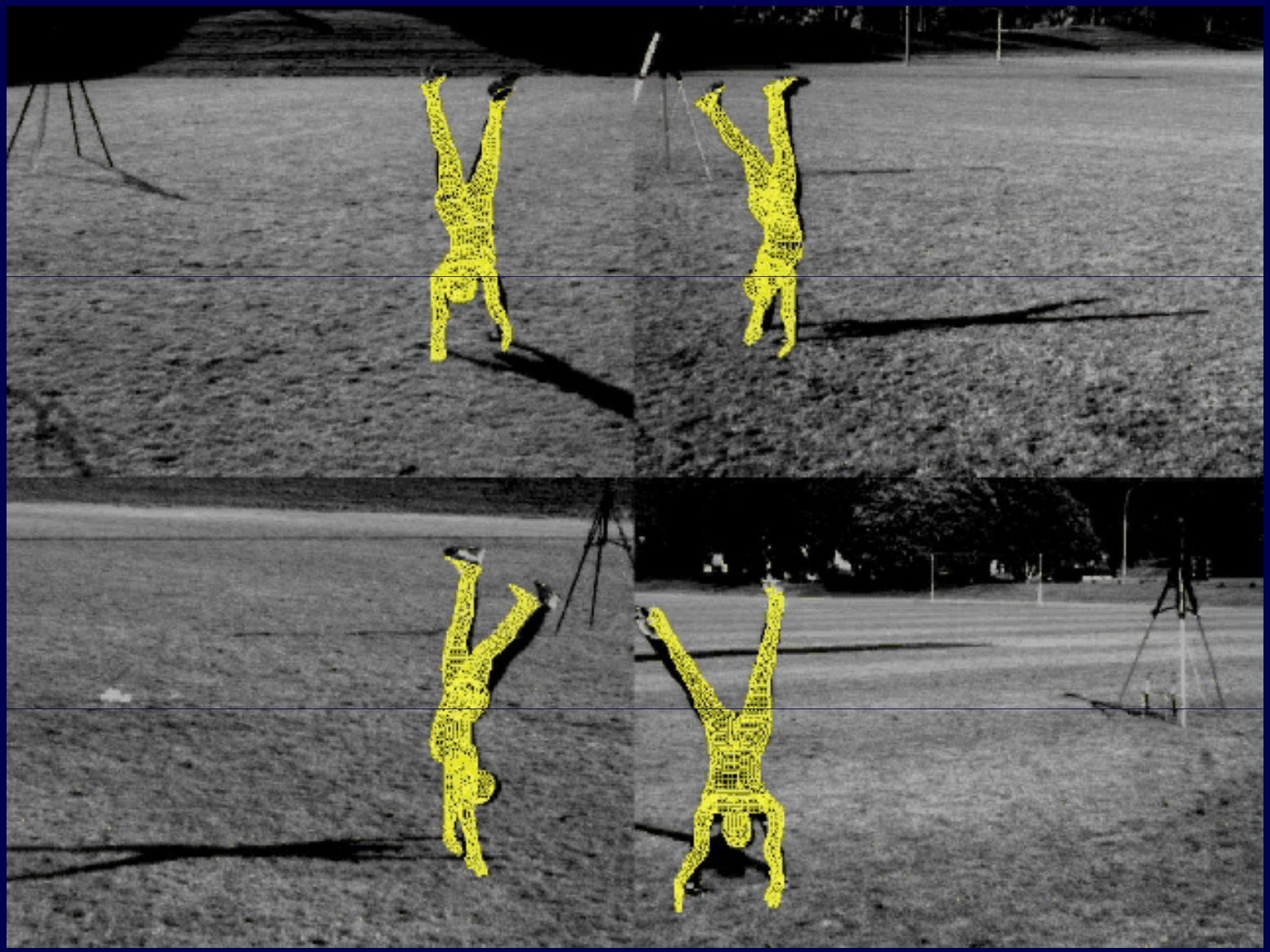


Brox, Rosenhahn, Gall, Cremers, PAMI '09

Markerless Motion Capture

Brox, Rosenhahn, Gall, Cremers, PAMI '09

Markerless Motion Capture



Brox, Rosenhahn, Gall, Cremers, PAMI '09

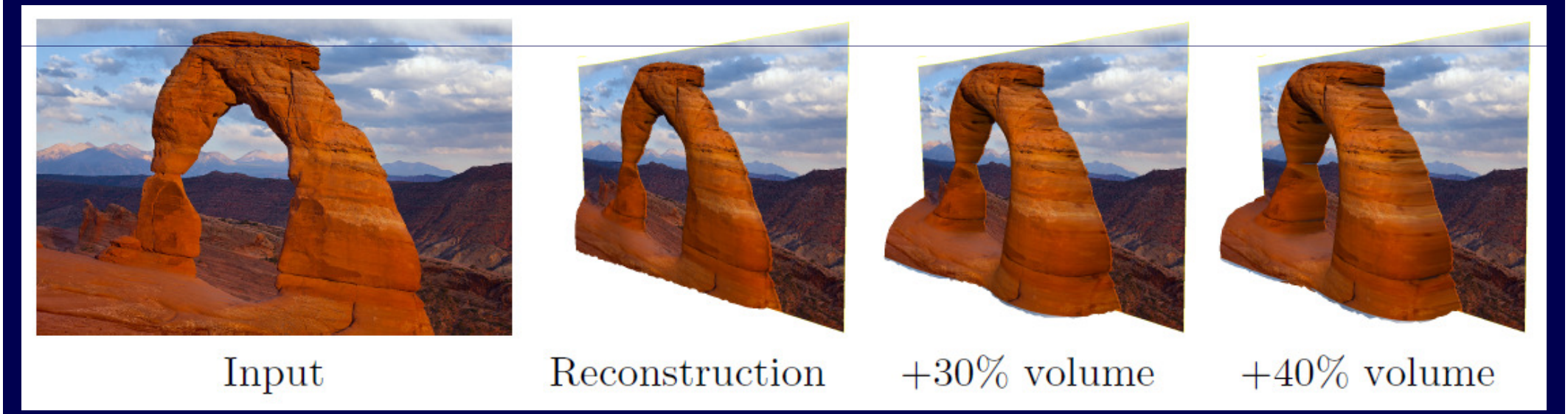
Single View Reconstruction

*Toeppe, Oswald, Rother, Cremers, ACCV 2010**

** Best Paper Honorable Mention*

In collaboration with Microsoft Research

Single View Reconstruction



*Toeppe, Oswald, Rother, Cremers, ACCV 2010**

** Best Paper Honorable Mention*

In collaboration with Microsoft Research

Single View Reconstruction

Toeppe, Oswald, Rother, Cremers, ACCV 2010

Single View Reconstruction

Toeppe, Oswald, Rother, Cremers, ACCV 2010

Denoising

Noisy input image f

Denoised image u_{den}

Rudin, Osher, Fatemi, Physica D '92

Deblurring

Original image

Blurred image

Deblurred image

Lions, Osher, Rudin, '92

Video Super-Resolution

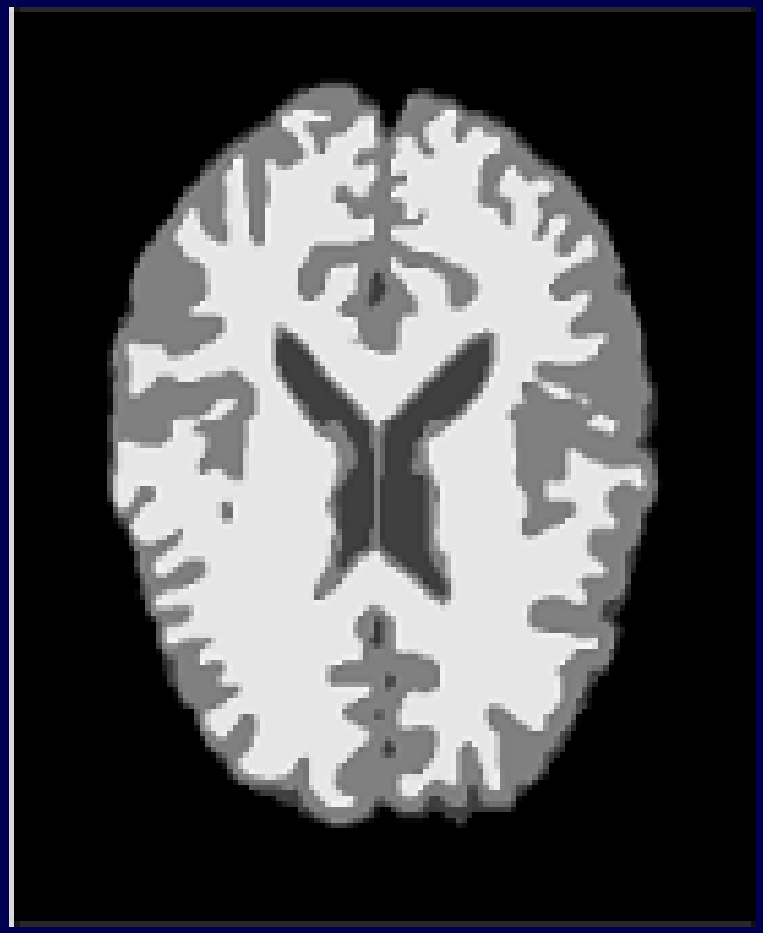
One of several input images

Super-resolution estimate

Schoenemann, Cremers, CVPR '08

Image Segmentation

Input image



segmentation

Chambolle, Cremers, Pock ’08, Pock et al. CVPR ’09

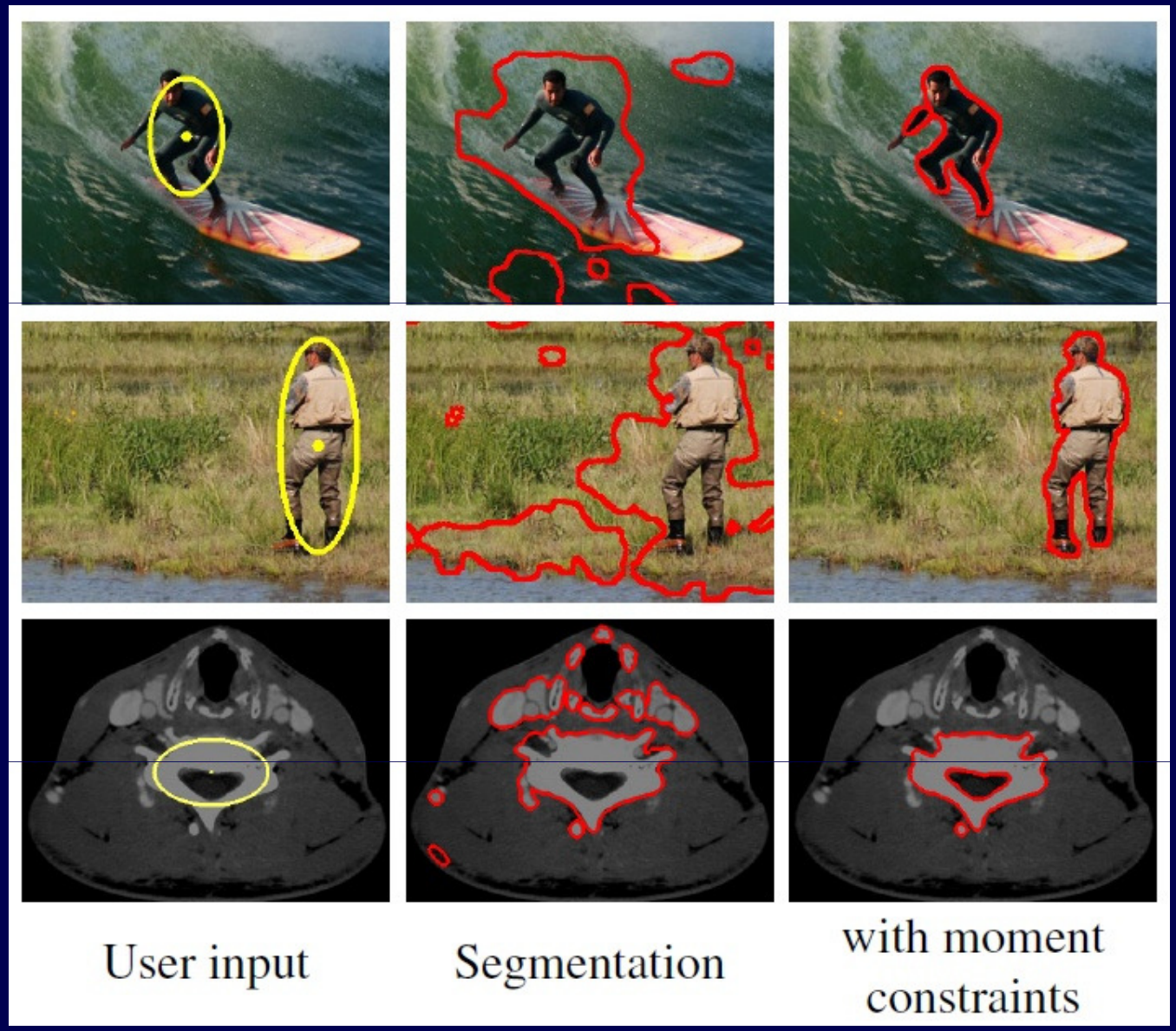
Interactive Segmentation

Nieuwenhuis, Toeppe, Cremers EMMCVPR '11

Interactive Segmentation

Nieuwenhuis, Toeppe, Cremers EMMCVPR '11

Interactive Segmentation

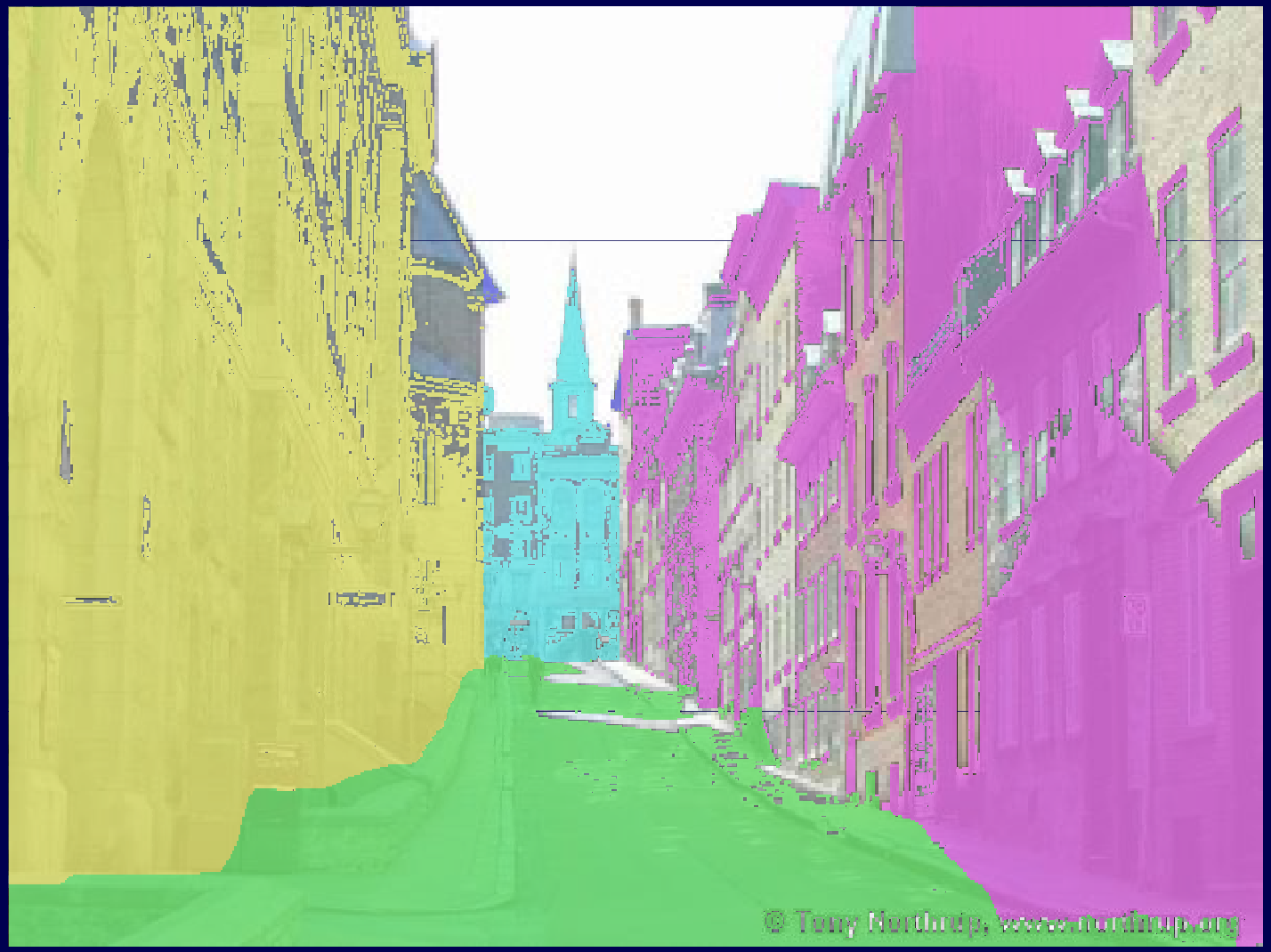


Klodt, Cremers ICCV '11

General Ordering Constraints

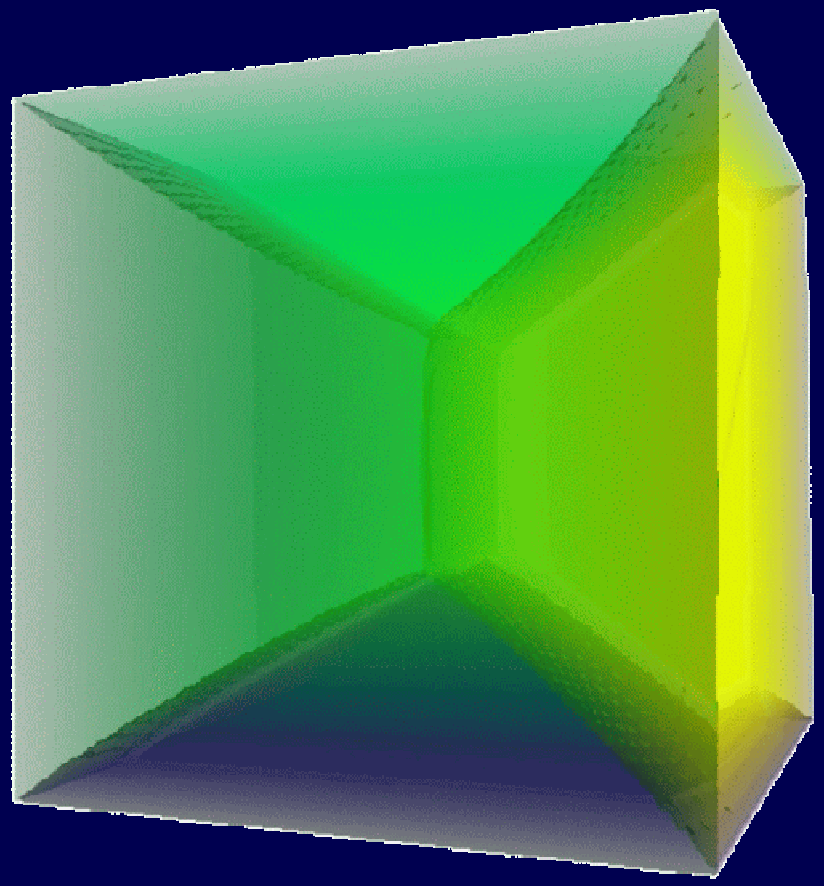
Strekalovskiy, Cremers, ICCV 2011

General Ordering Constraints

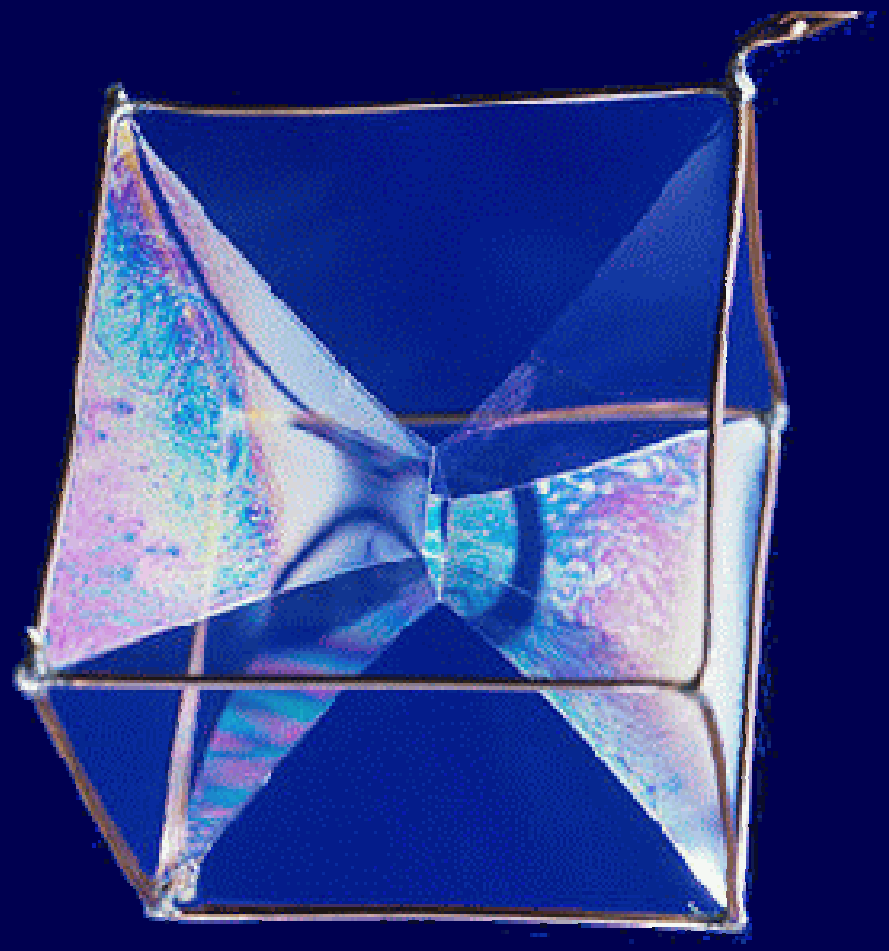


Strekalovskiy, Cremers, ICCV 2011

Minimal Partition in Nature



3D min partition inpainting



Soap film photo

Chambolle, Cremers, Pock '08, Pock et al. CVPR '09

Optical Flow

Input video

Optical flow field

Wedel et al., ICCV '09

Optical Flow

Input video

Optical flow field*

* 60 fps at 640 x 480 resolution

Wedel et al., ICCV '09

Optical Flow

Optical flow evaluation results: Average end-point error - Mozilla Firefox

Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

http://vision.middlebury.edu/flow/eval/results/results-e1.html

middlebury optic flow

Meistbesuchte Seiten Links anpassen LEO Deutsch-Englische... [DB] BAHN - Startseite ... WEB.DE Produkte - Fre...

Optical flow evaluation results

Statistics: Average SD R0.5 R1.0 R2.0 A50 A75 A95

Error type: angle end-point interpolation normalized interpolation

Average end-point error	avg. rank	Army (Hidden texture) GT all	Army im0 disc	Army im1 untext	Mequon (Hidden texture) GT all	Mequon im0 disc	Mequon im1 untext	Schefflera (Hidden texture) GT all	Schefflera im0 disc	Schefflera im1 untext	Wooden (Hidden texture) GT all	Wooden im0 disc	Wooden im1 untext	Grove (Synthetic) GT all	Grove im0 disc	Grove im1 untext	Urban (Synthetic) GT all	Urban im0 disc	Urban im1 untext	Yosemite (Synthetic) GT all	Yosemite im0 disc	Yosemite im1 untext	Teddy (Stereo) GT all	Teddy im0 disc	Teddy im1 untext
Adaptive [26]	3.9	**0.09** 1	**0.26** 1	**0.06** 1	0.23 7	0.78 6	0.18 6	0.54 9	1.19 10	0.21 4	**0.18** 1	0.91 2	**0.10** 1	0.88 3	1.25 3	0.73 4	**0.50** 1	**1.28** 1	**0.31** 1	0.14 9	0.16 9	0.22 9	**0.65** 1	1.37 2	0.79 3
Spatially variant [22]	5.5	0.10 3	0.27 4	0.08 3	0.22 4	0.75 4	0.19 7	0.43 4	1.00 5	**0.18** 1	0.19 2	1.05 4	**0.10** 1	1.05 8	1.41 9	1.16 12	0.59 4	1.61 5	0.43 3	0.13 5	**0.11** 1	0.28 15	0.96 9	1.72 8	1.28 12
TV-L1-improved [20]	6.2	**0.09** 1	**0.26** 1	0.07 2	0.20 3	0.71 3	0.16 2	0.53 8	1.18 9	0.22 5	0.21 5	1.24 11	0.11 3	0.90 4	1.31 5	0.72 2	1.51 11	1.93 9	0.84 8	0.18 15	0.17 11	0.31 16	0.73 5	1.62 6	0.87 4
Multicue MRF [24]	6.5	0.11 6	**0.26** 1	0.11 9	**0.19** 1	**0.53** 1	0.17 5	**0.24** 1	**0.49** 1	0.19 2	0.24 7	1.13 6	0.15 8	**0.79** 1	**1.10** 1	0.72 2	1.47 10	1.60 4	0.85 9	0.28 22	0.19 18	0.71 22	0.78 6	1.53 4	1.09 9
F-TV-L1 [18]	7.8	0.14 11	0.35 11	0.14 14	0.34 11	0.98 10	0.26 10	0.59 13	1.19 10	0.26 9	0.27 11	1.36 14	0.16 9	0.90 4	1.30 4	0.76 6	0.54 2	1.62 6	0.36 2	0.13 5	0.15 8	0.20 8	0.68 3	1.56 5	**0.66** 1
DPOF [21]	7.9	0.15 12	0.30 6	0.11 9	0.34 11	1.01 12	0.25 9	0.29 2	0.59 2	0.26 9	0.26 9	0.94 3	0.20 12	0.80 2	1.13 2	**0.63** 1	0.90 5	1.85 8	0.66 6	0.27 21	0.22 21	0.54 20	**0.65** 1	**1.20** 1	0.99 5
Fusion [9]	8.2	0.11 6	0.34 9	0.10 7	**0.19** 1	0.69 2	0.16 2	0.29 2	0.66 3	0.23 6	0.20 3	1.19 9	0.14 6	1.07 9	1.42 10	1.22 13	1.35 7	1.49 3	0.86 11	0.20 16	0.20 19	0.26 11	1.07 13	2.07 15	1.39 15
Brox et al. [8]	9.1	0.12 9	0.37 13	0.11 9	0.31 10	0.97 9	0.28 11	0.48 7	1.11 7	0.48 12	0.28 12	1.28 12	0.18 11	1.13 13	1.57 17	1.11 10	1.02 6	2.02 10	0.60 5	0.10 2	0.13 4	**0.11** 1	0.93 8	2.00 13	1.07 7
Dynamic MRF [10]	10.0	0.12 9	0.34 9	0.11 9	0.22 4	0.89 8	0.16 2	0.44 5	1.13 8	0.20 3	0.24 7	1.29 13	0.14 6	1.11 11	1.52 14	1.13 11	1.54 12	2.37 20	0.93 12	0.13 5	0.12 3	0.31 16	1.27 17	2.33 19	1.66 16
SegOF [13]	10.3	0.15 12	0.36 12	0.10 7	0.57 14	1.16 14	0.59 19	0.68 14	1.24 12	0.64 13	0.32 14	**0.86** 1	0.26 14	1.18 16	1.50 13	1.47 17	1.63 15	2.09 11	0.96 13	**0.08** 1	0.13 4	0.12 2	0.70 4	1.50 3	0.69 2
CBF [15]	10.3	0.10 3	0.28 5	0.09 5	0.29 8	0.79 6	0.29 12	0.45 6	0.98 4	0.24 8	0.21 5	1.22 10	0.13 5	0.96 6	1.39 8	0.74 5	2.32 23	2.19 14	1.29 20	0.34 24	0.27 25	0.85 24	0.86 7	1.78 9	1.06 6
Second-order prior [11]	11.4	0.10 3	0.30 6	0.08 3	0.22 4	0.85 7	**0.15** 1	0.57 12	1.28 14	0.23 6	0.20 3	1.14 7	0.11 3	1.13 13	1.55 16	1.03 9	2.52 24	2.45 21	1.25 19	0.42 25	0.25 24	1.09 26	0.98 11	1.92 10	1.07 7
Learning Flow [14]	12.2	0.11 6	0.32 8	0.09 5	0.29 8	0.99 11	0.23 8	0.55 10	1.24 12	0.29 11	0.36 15	1.56 16	0.25 13	1.25 18	1.64 19	1.41 16	1.55 14	2.32 19	0.85 9	0.14 9	0.18 15	0.24 10	1.09 14	2.09 17	1.27 11
Filter Flow [23]	12.7	0.17 15	0.39 15	0.13 13	0.43 13	1.09 13	0.38 13	0.75 15	1.34 15	0.78 18	0.70 18	1.54 15	0.68 18	1.13 13	1.38 7	1.51 18	0.57 3	1.32 2	0.44 4	0.22 18	0.23 22	0.26 11	0.96 9	1.66 7	1.12 10
GraphCuts [17]	12.9	0.16 14	0.38 14	0.14 14	0.59 17	1.36 18	0.46 14	0.56 11	1.07 6	0.64 13	0.26 9	1.14 7	0.17 10	0.96 6	1.35 6	0.84 8	2.25 22	1.79 7	1.22 18	0.22 18	0.17 11	0.43 19	1.22 16	2.05 14	1.76 18
Black & Anandan 3 [7]	13.8	0.18 16	0.42 16	0.19 18	0.58 16	1.31 16	0.50 15	0.95 19	1.58 18	0.70 15	0.49 16	1.59 17	0.45 16	1.08 10	1.42 10	1.22 13	1.43 8	2.28 17	0.83 7	0.15 11	0.17 11	0.17 5	1.11 15	1.98 12	1.30 13
SPSA-learn [16]	14.3	0.18 16	0.45 17	0.17 16	0.57 14	1.32 17	0.51 16	0.84 16	1.50 16	0.72 16	0.52 17	1.64 18	0.49 17	1.12 12	1.42 10	1.39 15	1.75 16	2.14 12	1.06 16	0.13 5	0.13 4	0.19 6	1.32 18	2.08 16	1.73 17
GroupFlow [12]	15.1	0.21 18	0.51 18	0.21 19	0.79 21	1.69 22	0.72 21	0.86 17	1.64 19	0.74 17	0.30 13	1.07 5	0.26 14	1.29 20	1.81 21	0.82 7	1.94 17	2.30 18	1.36 21	0.11 4	0.14 7	0.19 6	1.06 12	1.96 11	1.35 14
2D-CLG [3]	16.8	0.28 22	0.62 23	0.21 19	0.67 20	1.21 15	0.70 20	1.12 21	1.80 22	0.99 21	1.07 23	2.06 21	1.12 23	1.23 17	1.52 14	1.62 21	1.54 12	2.15 13	0.96 13	0.10 2	**0.11** 1	0.16 4	1.38 19	2.26 18	1.83 19
Horn & Schunck [6]	17.9	0.22 20	0.55 21	0.22 21	0.61 18	1.53 20	0.52 17	1.01 20	1.73 20	0.80 19	0.78 20	2.02 20	0.77 20	1.26 19	1.58 18	1.55 20	1.43 8	2.59 22	1.00 15	0.16 13	0.18 15	0.15 3	1.51 20	2.50 20	1.88 20
Black & Anandan 2 [2]	17.9	0.21 18	0.52 19	0.17 16	0.65 19	1.52 19	0.58 18	0.93 18	1.54 17	1.03 22	0.76 19	1.97 19	0.73 19	1.40 21	1.80 20	1.54 19	2.04 19	2.22 15	1.12 17	0.15 11	0.17 11	0.26 11	1.68 21	2.64 21	2.06 21
Black & Anandan [1]	21.1	0.26 21	0.54 20	0.27 22	0.99 22	1.61 21	1.07 22	1.23 22	1.77 21	1.14 24	0.98 21	2.10 22	0.97 21	1.59 24	1.97 24	1.95 22	2.19 21	2.26 16	1.41 23	0.20 16	0.18 15	0.41 18	2.34 22	3.46 25	2.98 22
STOB [25]	21.6	0.30 24	0.70 24	0.36 24	1.09 23	1.77 23	1.21 23	1.25 24	1.98 24	1.03 22	1.56 24	2.26 24	1.71 25	1.54 23	1.82 22	2.14 24	2.02 18	2.79 24	1.36 21	0.17 14	0.16 9	0.26 11	2.43 23	3.18 22	3.31 24
FOLKI [19]	23.0	0.29 23	0.73 25	0.33 23	1.52 25	1.96 25	1.80 25	1.23 22	2.04 26	0.95 20	0.99 22	2.20 23	1.08 22	1.53 22	1.85 23	2.07 23	2.14 20	3.23 26	1.60 24	0.26 20	0.21 20	0.68 21	2.67 25	3.27 23	4.32 25
Pyramid LK [4]	25.0	0.39 25	0.61 22	0.61 26	1.67 26	1.78 24	2.00 26	1.50 26	1.97 23	1.38 26	1.57 25	2.39 25	1.78 26	2.94 26	3.72 26	2.98 26	3.33 26	2.74 23	2.43 26	0.30 23	0.24 23	0.73 23	3.80 26	5.08 26	4.88 26

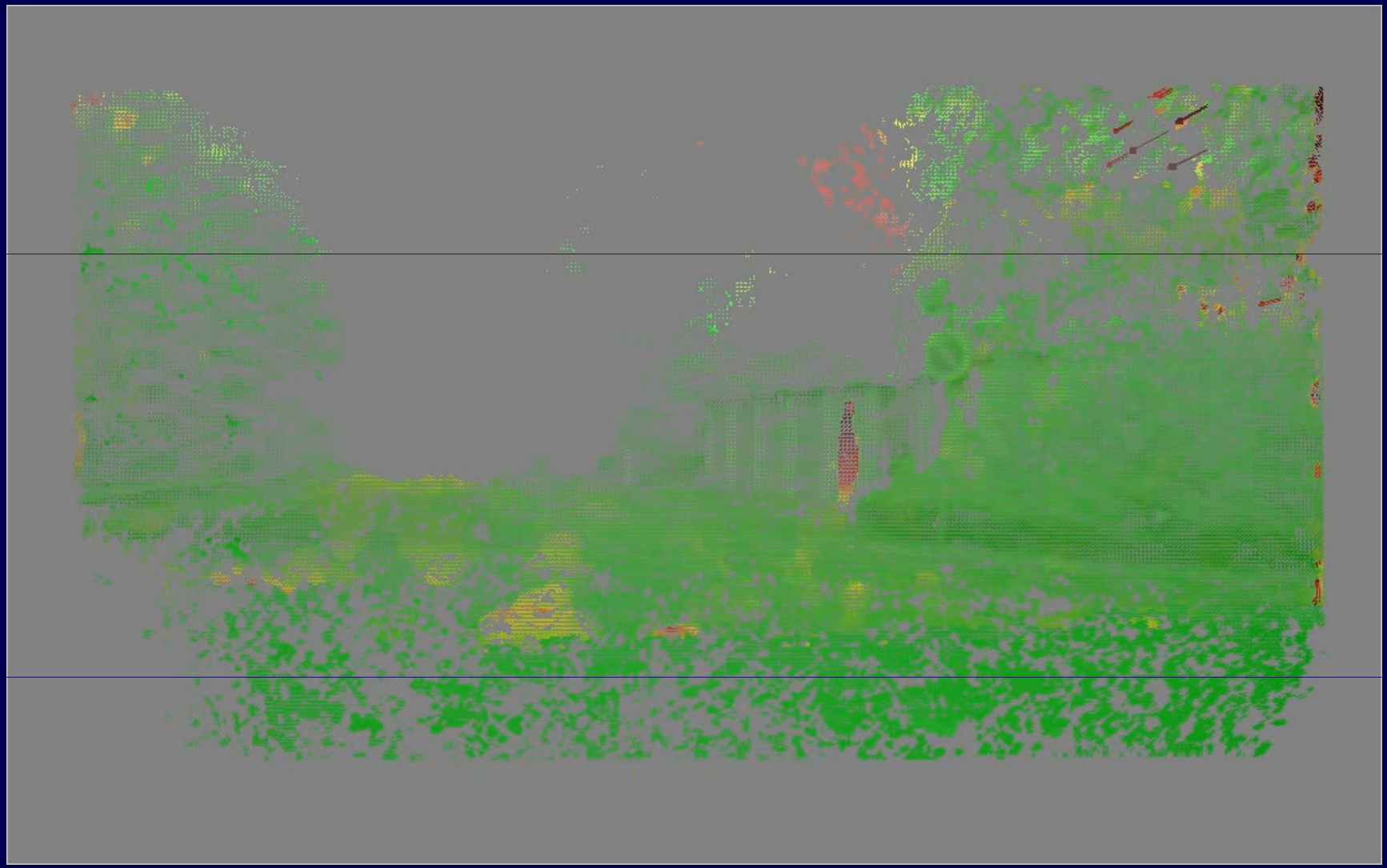
Wedel et al. '09

Scene Flow: Geometry & 3D Motion

*Wedel et al., ECCV '08 **

* In collaboration with Daimler Research.

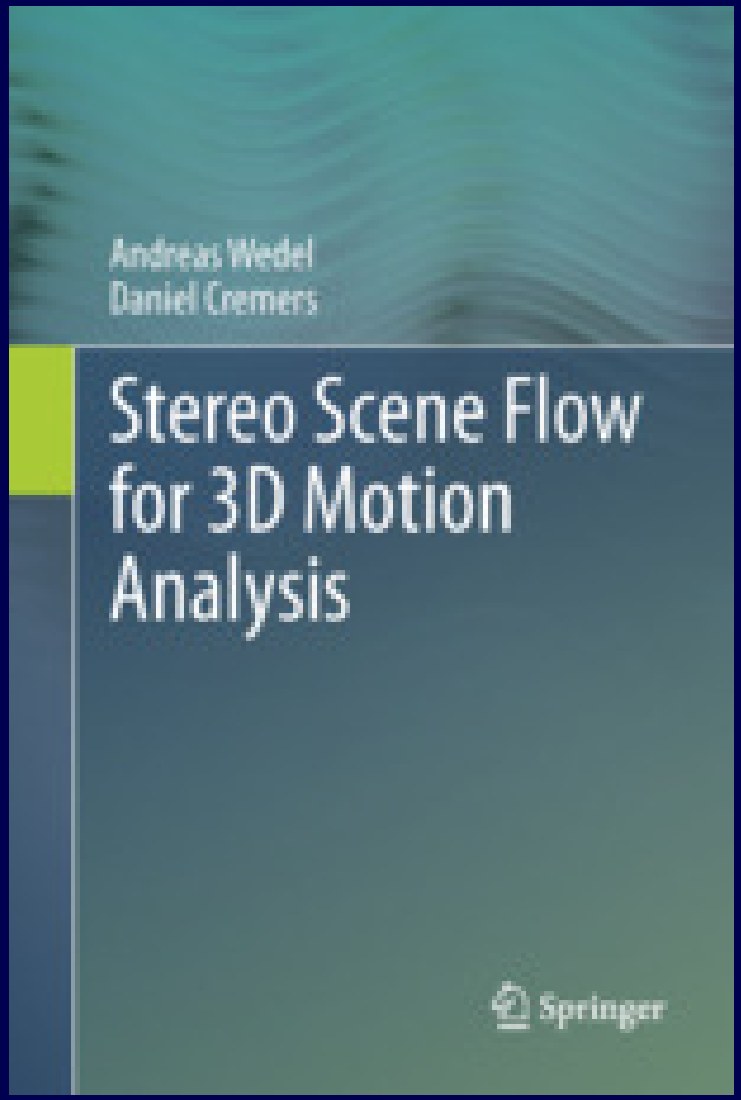
Scene Flow: Geometry & 3D Motion



*Wedel et al., ECCV '08 **

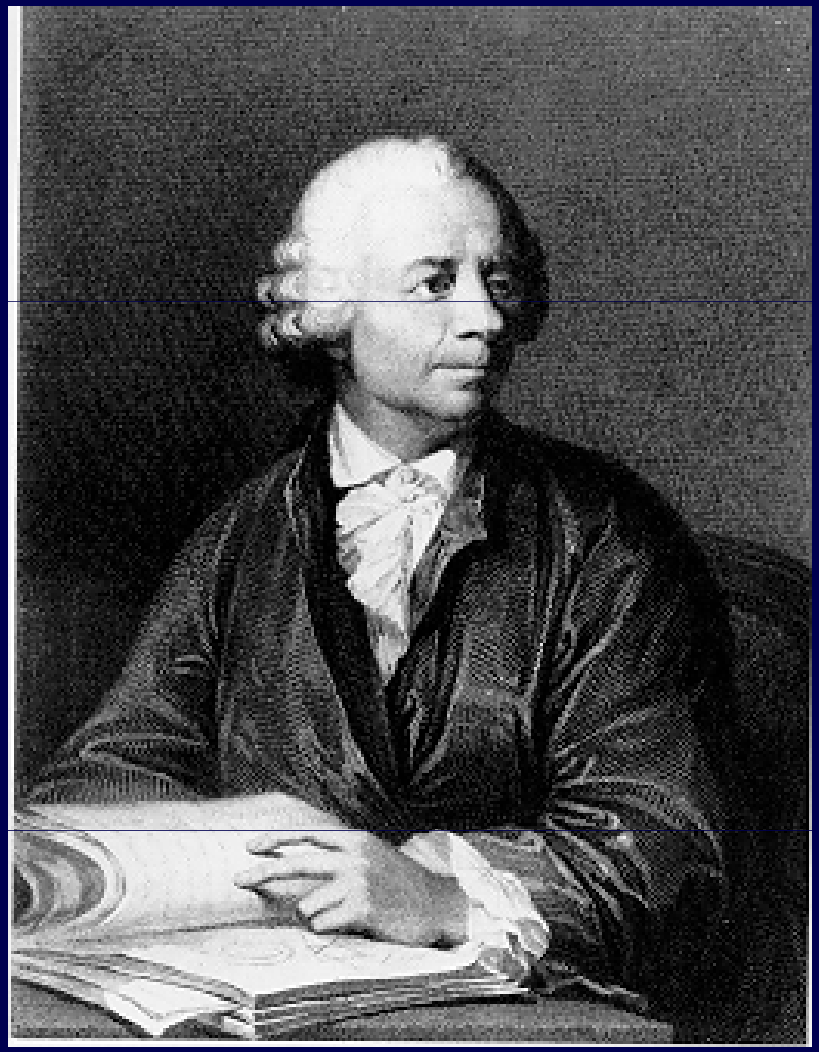
* In collaboration with Daimler Research.

Book on Optical Flow & Scene Flow

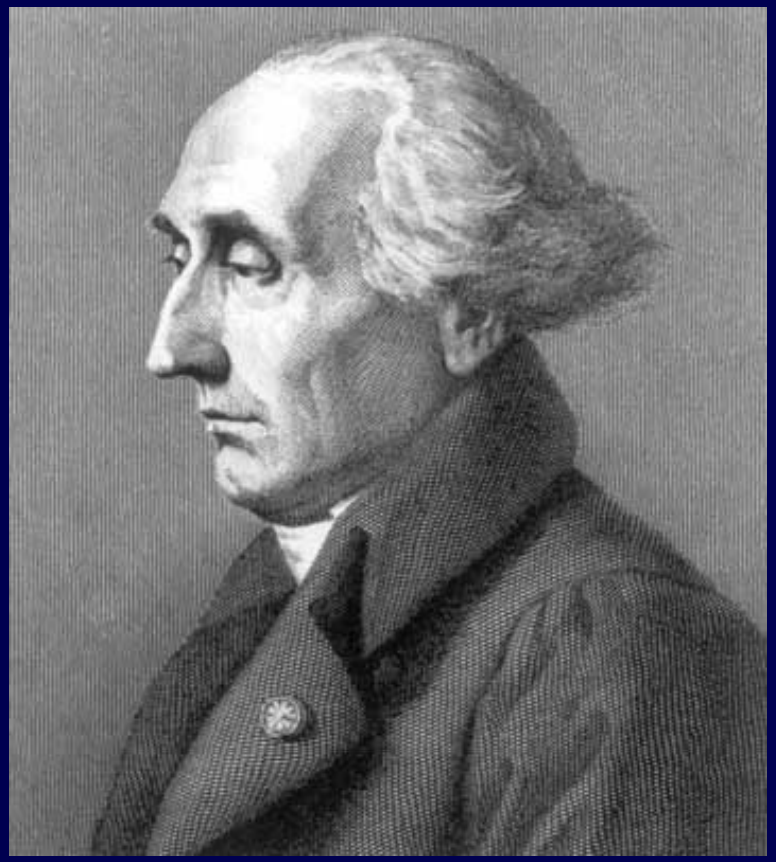


Wedel, Cremers, Springer 2011

The Pioneers of Variational Methods



Leonhard Euler
(1703-1783)



Joseph-Louis Lagrange
(1736 – 1813)