Seminar: Recent Advances in 3D Computer Vision

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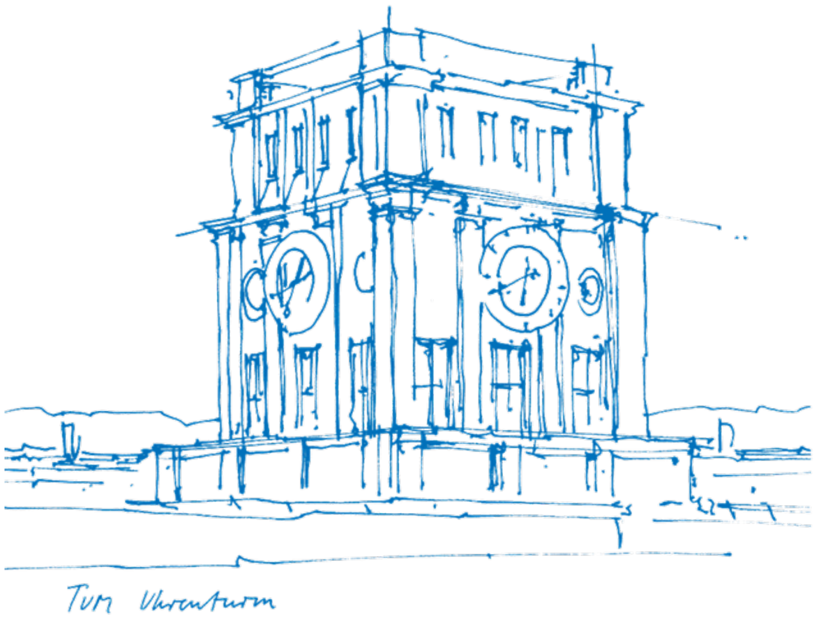
Technical University of Munich



How can I access these slides?

- Option 1 (preferred): seminar web page
  - https://vision.in.tum.de/teaching/ws2019/seminar_realtime3d and https://vision.in.tum.de/teaching/ws2019/seminar_3dgeometry
  - Passwords for material pages: realtime3d_ws19 and 3dgeometry_ws19
  - Material pages will soon go online
- Option 2: contact organizers
  - realtime3d-ws19@vision.in.tum.de and 3dgeometry-ws19@vision.in.tum.de
  - **Only use this option if you forgot the password**

Outline

- General Information
  - About the Seminar
  - Registration
- Possible Papers: The Evolution of Motion Estimation and Real-time 3D Reconstruction
  - Depth Sensors
  - Monocular Cameras
  - Semantic Tracking and Mapping
  - Event-based Cameras
  - Learning-based Methods
- Possible Papers: An Overview of Methods for Accurate Geometry Reconstruction
  - Multi-view Reconstruction
  - Shading-based Approaches
  - Reconstruction from Point Clouds
  - Learning-based Geometry Estimation
- Questions

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How is the seminar organized?

- Seminar meetings: talks and discussion
  - Time: Wednesdays, 10:00 - 12:00, every second week
  - Room: MI 02.09.023
  - Starting date: TBA (web page)
  - Two talks per week
  - **Attendance is mandatory!**
- Talk preparation / contact with supervisor
  - Read through your paper and write down what you don't understand
  - Approx. **one month before** talk (optional, but recommended): meet supervisor for questions
  - **One week before** talk (optional, but recommended): meet supervisor to go through slides
  - **One week before** talk (mandatory): send slides to your supervisor
  - **Two weeks after** talk (mandatory): submit your report via email

What about the presentation?

- General set-up:
  - Duration: 20-25 minutes talk + 10-15 minutes discussion
  - Make sure to finish on time - not too early and not too late!
  - Rule of thumb: 1-2 minutes per slide $\rightarrow$ 10-20 slides
  - Do not put too much information on the slides!
- Recommended structure (talk only):
  - Introduction
  - Overview / Outline
  - Method description
  - Experiments and results
  - Personal comments
  - Summary

What about the discussion after each talk?

- Discussion afterwards **will** influence your grade
- Ask questions!
- There are **no** stupid questions!

What about the final report?

- General set-up:
  - Use LaTeX template provided on web page
  - Length: 3-4 pages
  - Send final report as pdf by email to `realtime3d-ws19@vision.in.tum.de` or `3dgeometry-ws19@vision.in.tum.de`, depending on which seminar you attend
  - Submission deadline: **two weeks after talk**
- Recommended structure (main text only):
  - Introduction
  - Method description
  - Experiments and results
  - Discussion of results
  - Summary

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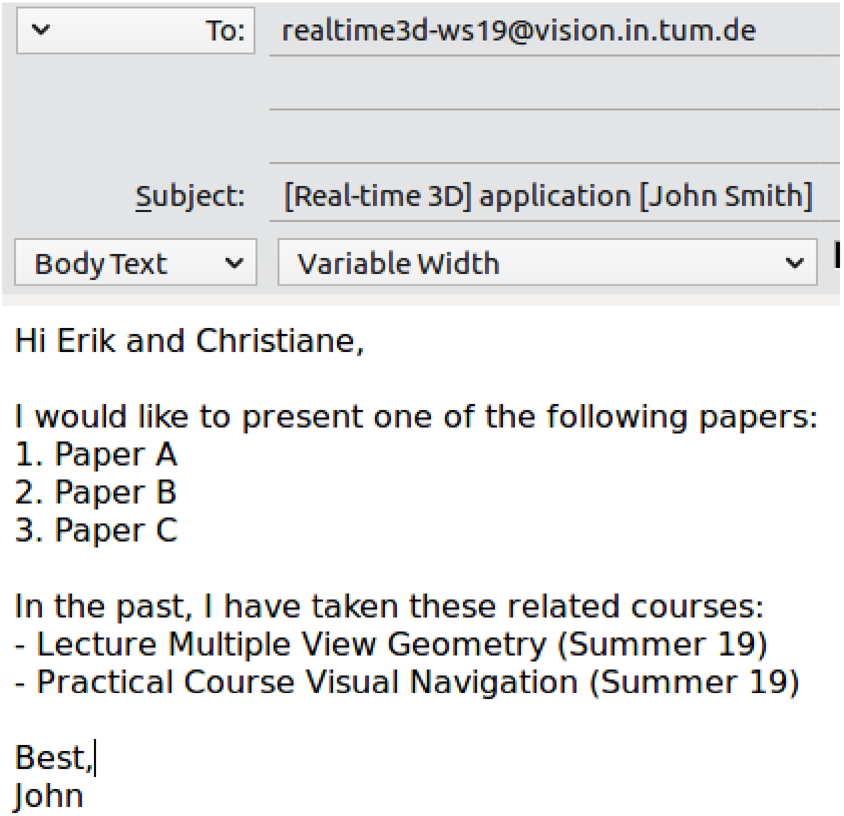
How do you register for the seminar?

- Step 1: Official registration via TUM matching system
  - Go to `matching.in.tum.de`
  - Register for seminar you want to attend
- Step 2: Personal registration via email
  - In the list of papers on the web page, select your three favorites
  - Write an email ranking these three favorites to the seminar email address
  - Email subject: “[seminar short title] application [your name]”
  - Include information about related lectures / courses you have taken so far.
  - We do **not** need your CV or a motivation letter!
  - Registrations without email / emails with missing information will be ignored!
- Deadline for both registrations: July 24, 2019

How do you register for the seminar?

Example registration email:



To: realtime3d-ws19@vision.in.tum.de

Subject: [Real-time 3D] application [John Smith]

Body Text | Variable Width

Hi Erik and Christiane,

I would like to present one of the following papers:
1. Paper A
2. Paper B
3. Paper C

In the past, I have taken these related courses:
- Lecture Multiple View Geometry (Summer 19)
- Practical Course Visual Navigation (Summer 19)

Best,
John

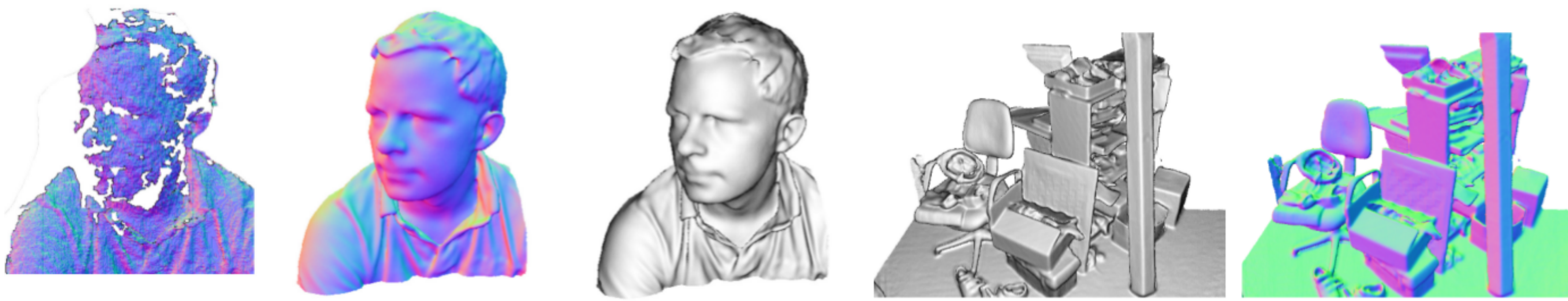
How do we select candidates and assign papers?

- Candidate selection
  - Only students registered in the matching system **AND** emails containing all required information will be considered
  - Among students meeting the formal criteria, selection will be random
  - You will get notified by the matching system about the decision (July 30, 2019)
- Paper assignment
  - Papers are assigned after the participant list is finalized
  - We give our best to accommodate your preference list in the assignment

Outline

KinectFusion: Real-Time Dense Surface Mapping and Tracking

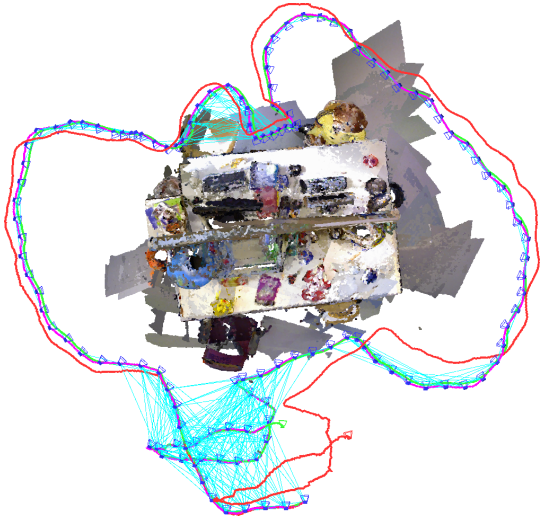
Newcombe, Izadi, Hilliges, Molyneaux, Kim, Davison, Kohli, Shotton, Hodges, Fitzgibbon 2011



- First paper to generate dense 3D models in real-time using depth sensor and GPU
- Highly cited, impactful, baseline method for 3D reconstruction using RGB-D cameras

Dense Visual SLAM for RGB-D Cameras

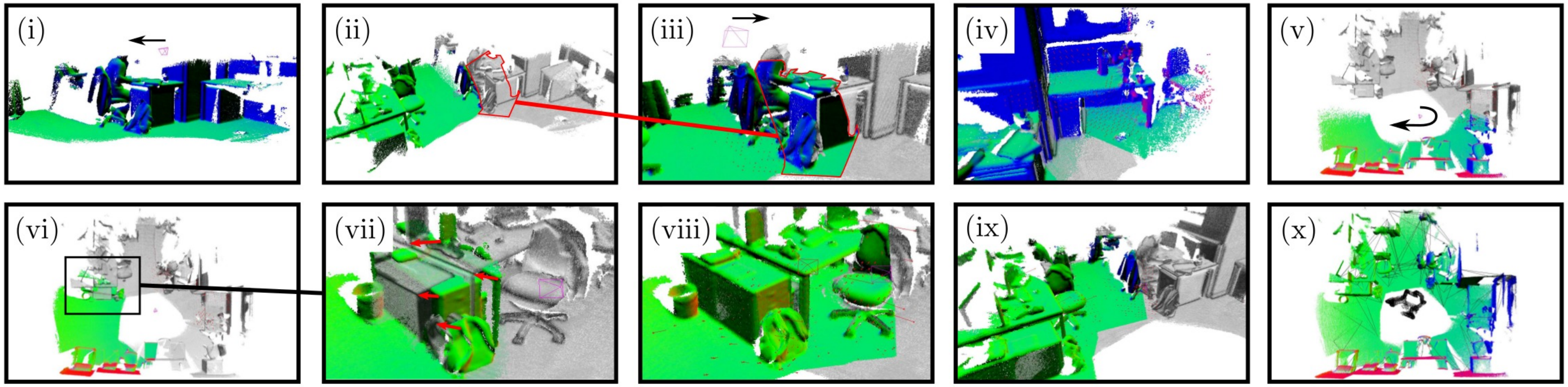
Kerl, Sturm, Cremers 2013



- Odometry method that uses both geometry and color information
- Uses a new distribution of the depth to improve the pose estimation

ElasticFusion: Dense SLAM Without A Pose Graph

Whelan, Leutenegger, Salas-Moreno, Glocker, Davison 2015



- Uses surfels instead of a TSDF to represent the 3D model
- First method to update the surface in online manner

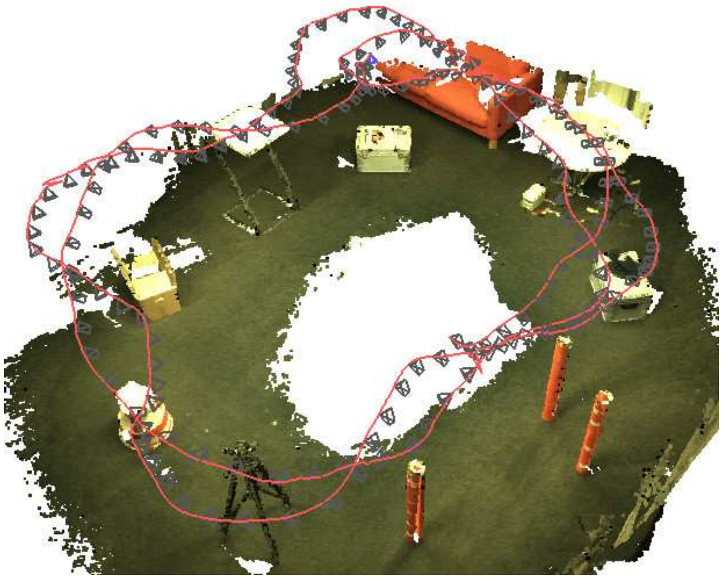
BundleFusion: Real-Time Globally Consistent 3D Reconstruction Using On-the-Fly Surface Reintegration

Dai, Nießner, Zollhöfer, Izadi, Theobalt 2017

- Use all depth and color data to obtain consistent mapping
- Uses bundle adjustment to avoid drift and can recompute the surface during scan.

BAD SLAM: Bundle Adjusted Direct RGB-D SLAM

Schöps, Sattler, Pollefeys 2019



- Published on CVPR 2019 this year
- Perform bundle adjustment on surfels to get a high quality pose

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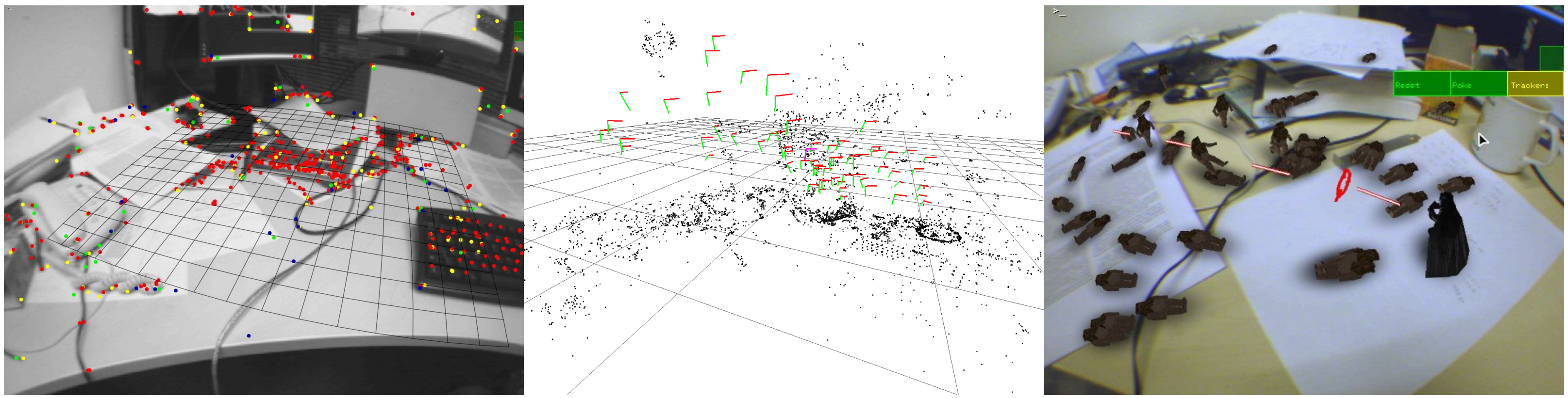
PTAM: Parallel Tracking and Mapping

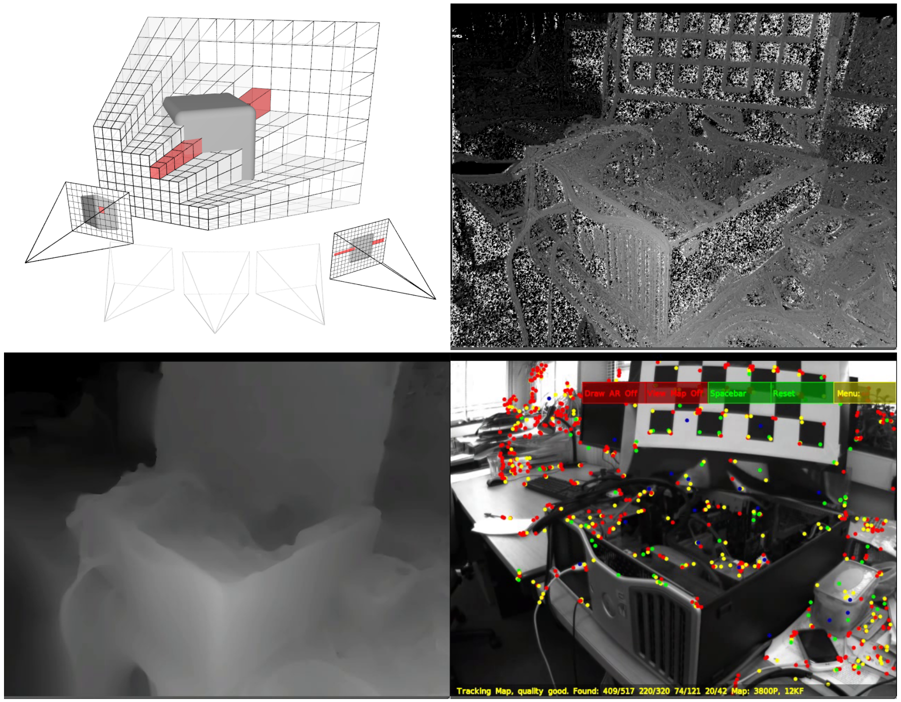
Klein, Murray 2007



- One of the first systems capable of estimating both pose and geometry in real-time for handheld cameras
- Simple AR applications

DTAM: Dense Tracking and Mapping in Real-Time

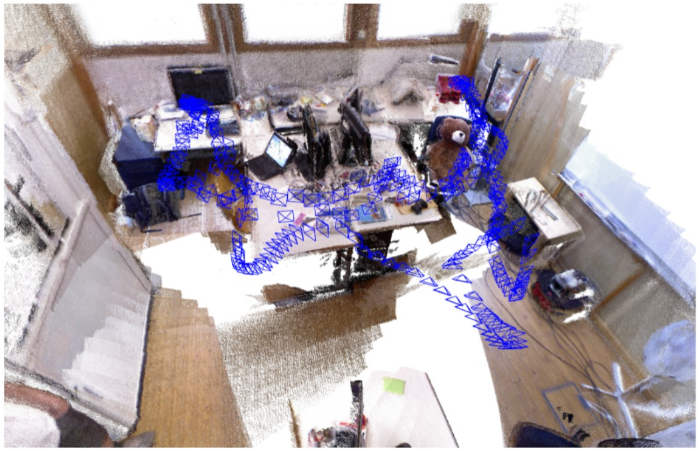
Newcombe, Lovegrove, Davison 2011



- One of the first monocular systems to create dense 3D models

ORB-SLAM: a Versatile and Accurate Monocular SLAM System

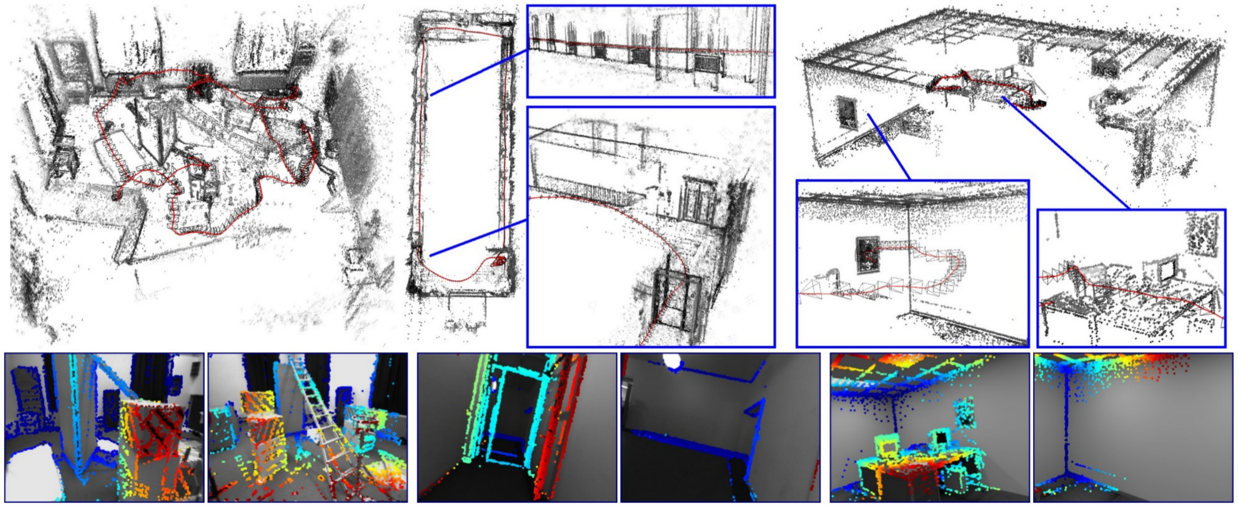
Mur-Artal, Montiel, Tardós 2015



- Use all depth and color data to obtain consistent mapping

Direct Sparse Odometry

Engel, Koltun, Cremers 2016



- Large-scale odometry
- Does not rely on keypoint detections

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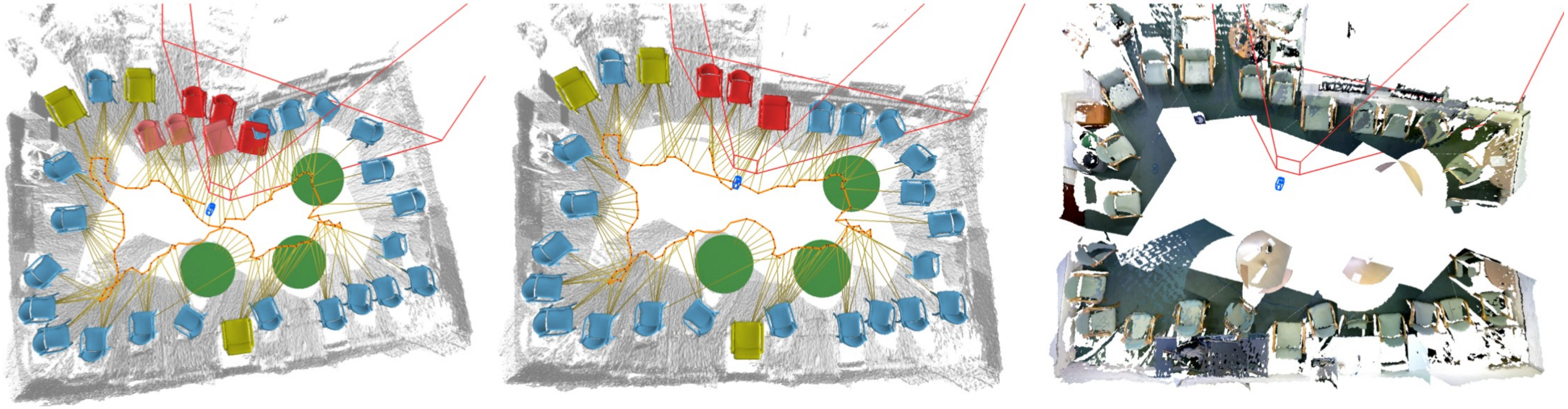
SLAM++: Simultaneous Localisation and Mapping ad the Level of Objects

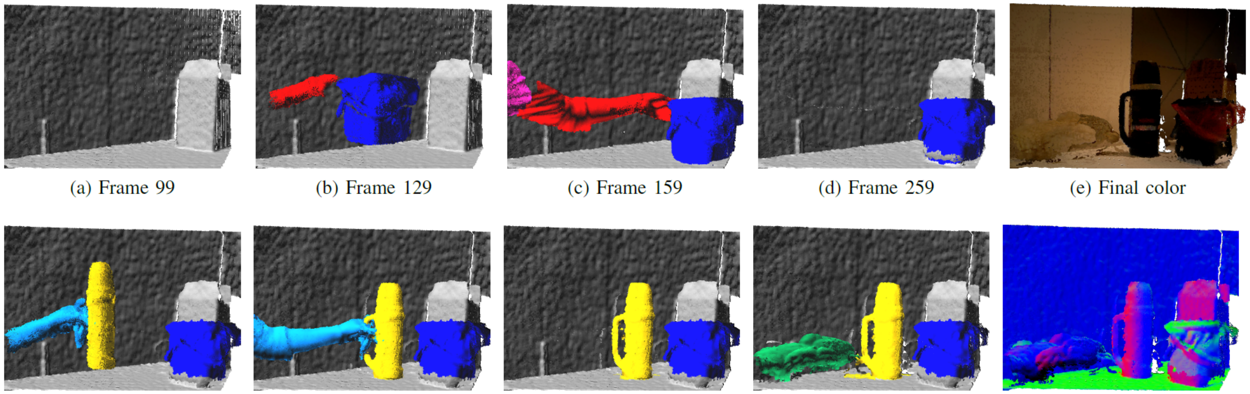
Salas-Moreno, Newcombe, Strasdat, Kelly, Davison 2013



- Semantic 3D reconstruction
- Classifies different objects on the fly

Co-Fusion: Real-time Segmentation, Tracking and Fusion of Multiple Objects

Rünz, Agapito 2017



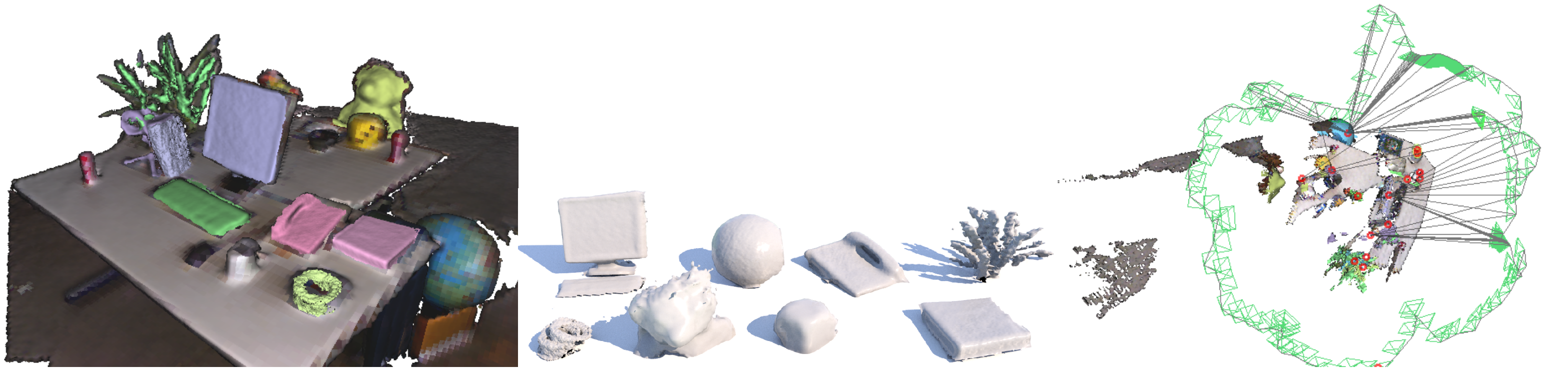
(a) Frame 99 (b) Frame 129 (c) Frame 159 (d) Frame 259 (e) Final color

(f) Frame 539 (g) Frame 599 (h) Frame 679 (i) Frame 929 (j) Final normals

- Semantic 3D Reconstruction
- Allows objects to move

Fusion++: Volumetric Object-Level SLAM

McCormac, Clark, Bloesch, Davison, Leutenegger 2018



- Volumetric Object-Level Reconstructions
- Can handle dynamic motions

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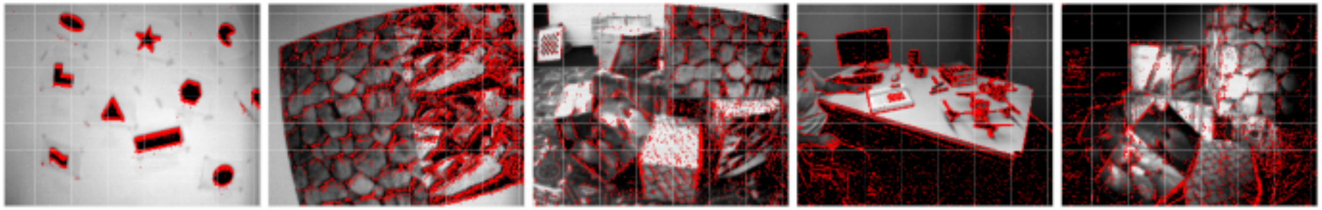
Event-Based Visual Inertial Odometry

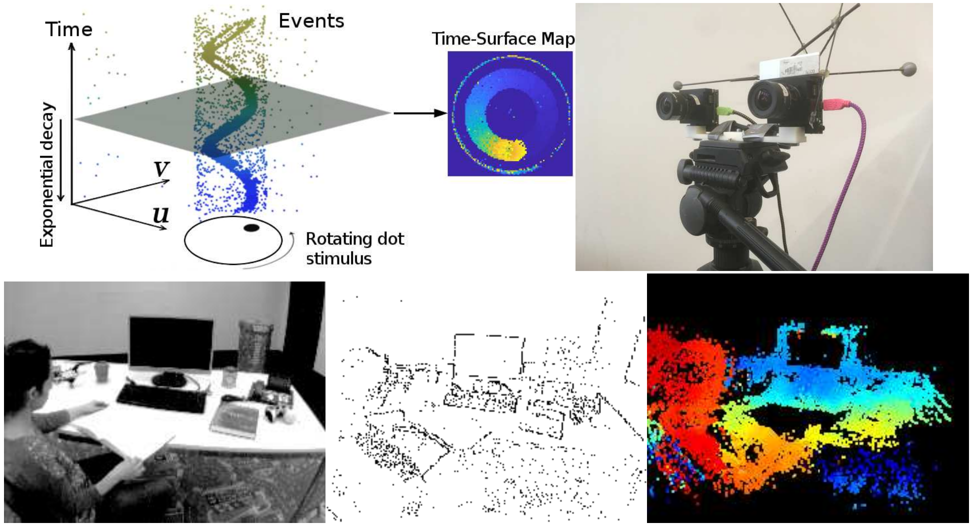
Zhu, Atanasov, Daniilidis 2017



- Each pixel detects a change in the scene
- Much higher frame rate and no motion-blur
- Golf images obtained from https://www.prophesee.ai/2018/06/25/event-based-vision-2/

Semi-Dense 3D Reconstruction with a Stereo Event Camera

Zhou, Gallego, Rebecq, Kneip, Li, Scaramuzza 2018



- Creates semi-dense depth images using an event-based stereo rig

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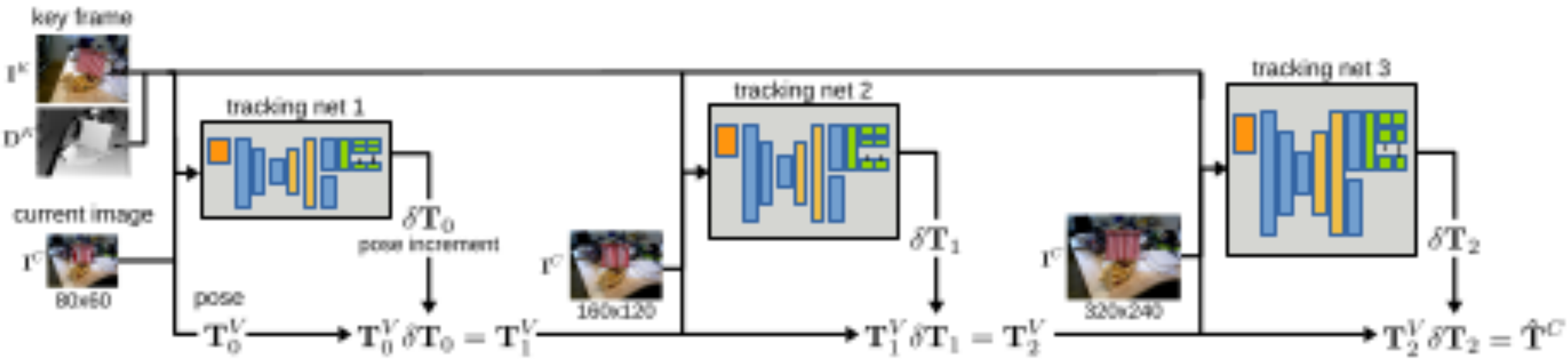
DeepTAM: Deep Tracking and Mapping

Zhou, Ummenhofer, Brox 2018



- Learn a network to predict the pose and generate depth images

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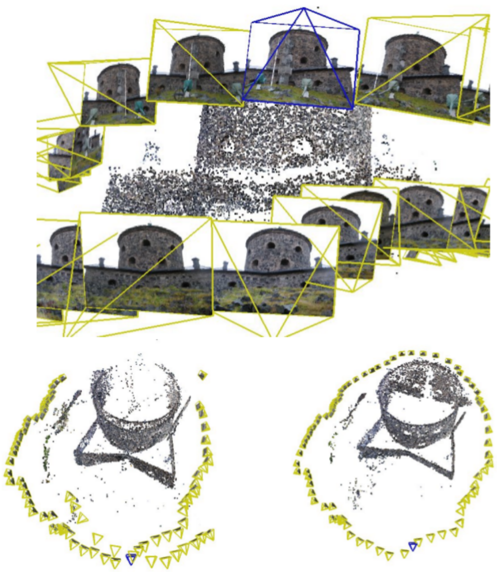
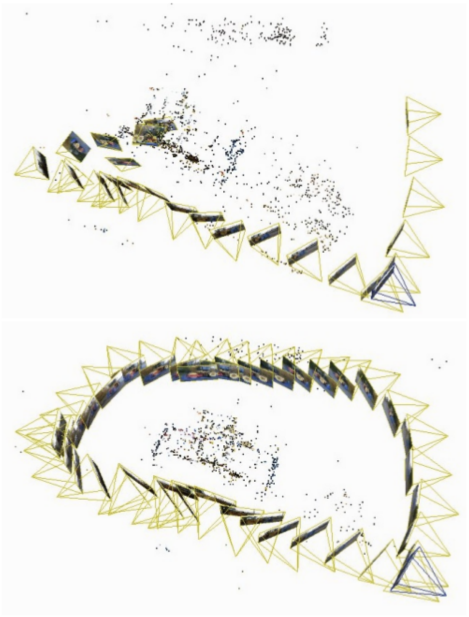
Non-Sequential Structure from Motion

Enqvist, Kahl, Olsson 2011





- Simultaneous consistent alignment of multiple RGB images
- Uses concepts from epipolar geometry, such as essential matrices

Color map optimization for 3D reconstruction with consumer depth cameras

Zhou, Koltun 2014

Input   Optimized reconstruction

- Optimize color using photoconsistency assumption
- Non-rigid correction

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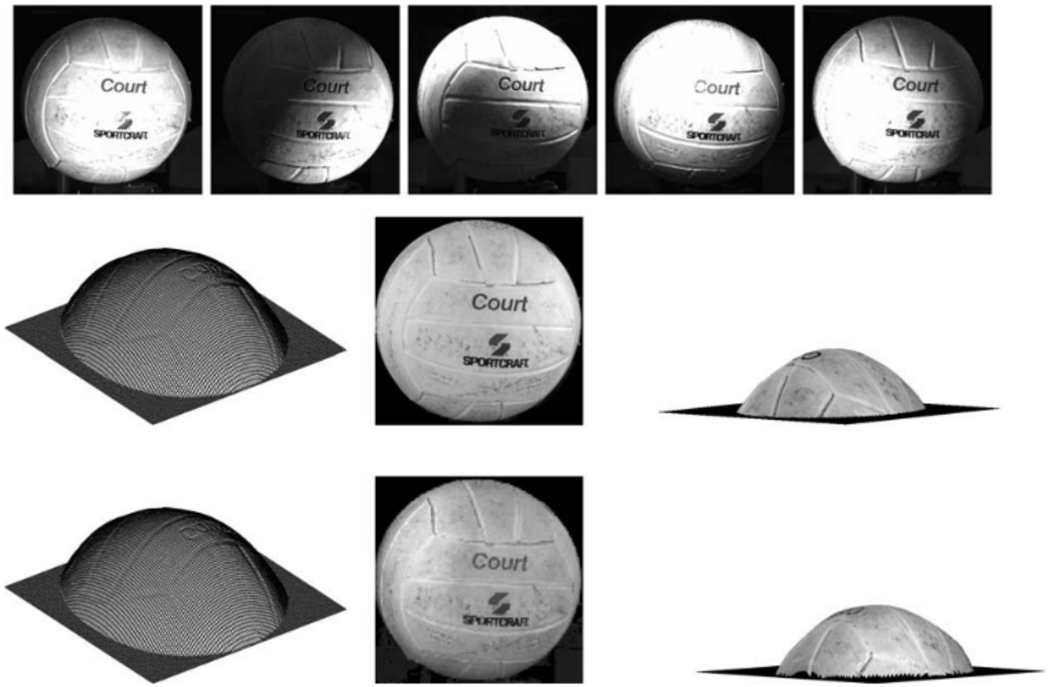
Photometric Stereo with General, Unknown Lighting

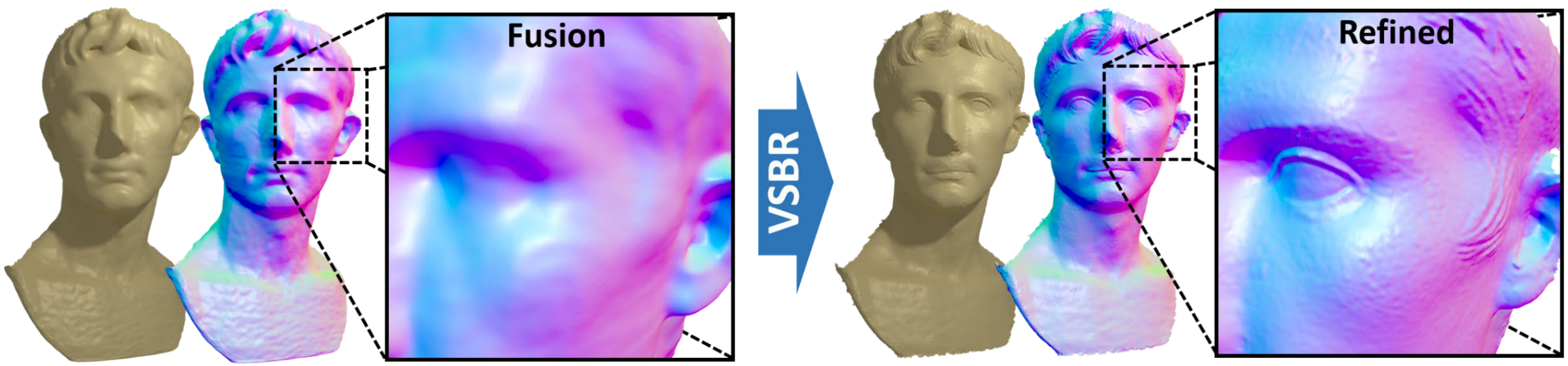
Basri, Jacobs, Kemelmacher 2007



- Reconstruct shape from multiple images with different lighting

Shading-based Refinement on Volumetric Signed Distance Functions

Zollhöfer, Dai, Innmann, Wu, Stamminger, Theobalt, Nießner 2015



- Optimize geometry using shading (color) information
- Use signed distance functions to represent geometry

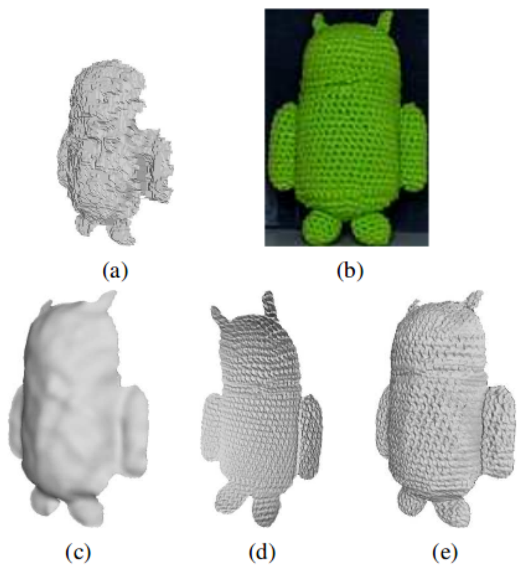
RGBD-Fusion Real-Time High Precision Depth Recovery

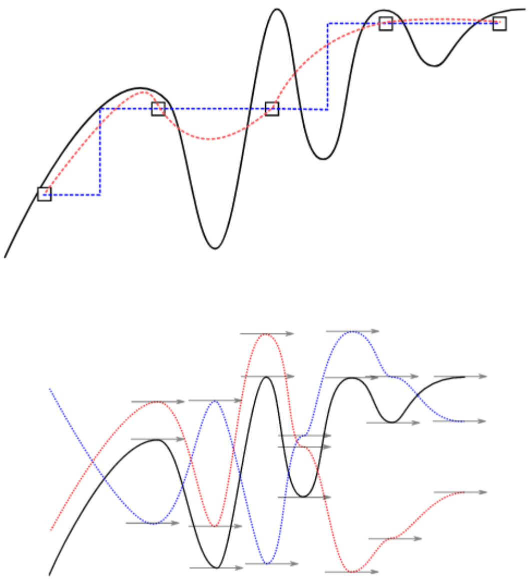
Or-El, Rosman, Wetzler, Kimmel, Bruckstein 2015

- From a single RGB-D shot improve the underlying depth map
- Use shape-from-shading and smart optimization

Fight ill-posedness with ill-posedness: Single-shot variational depth super-resolution from shading

Haefner, Quéau, Möllenhoff, Cremers 2018

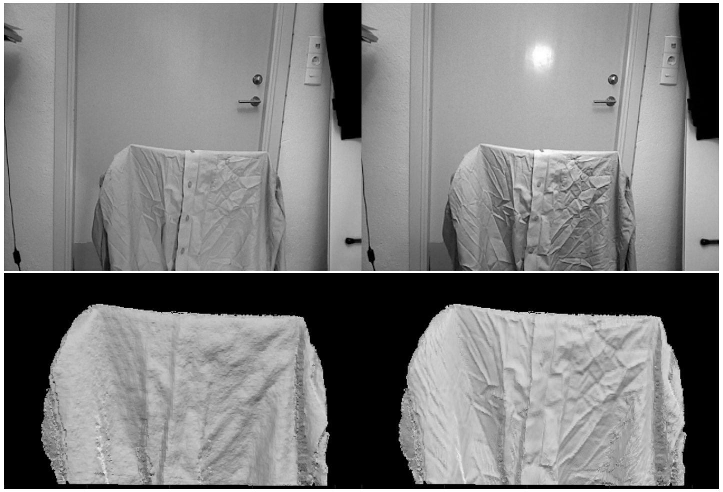




- Generate super-resolved depth image using shading clues
- Overcome shading ambiguity using depth clues

Combining Depth Fusion and Photometric Stereo for Fine-Detailed 3D Models

Bylow, Maier, Kahl, Olsson 2019



- Vary light source and move the depth sensor
- Refine the normals to get a higher accuracy

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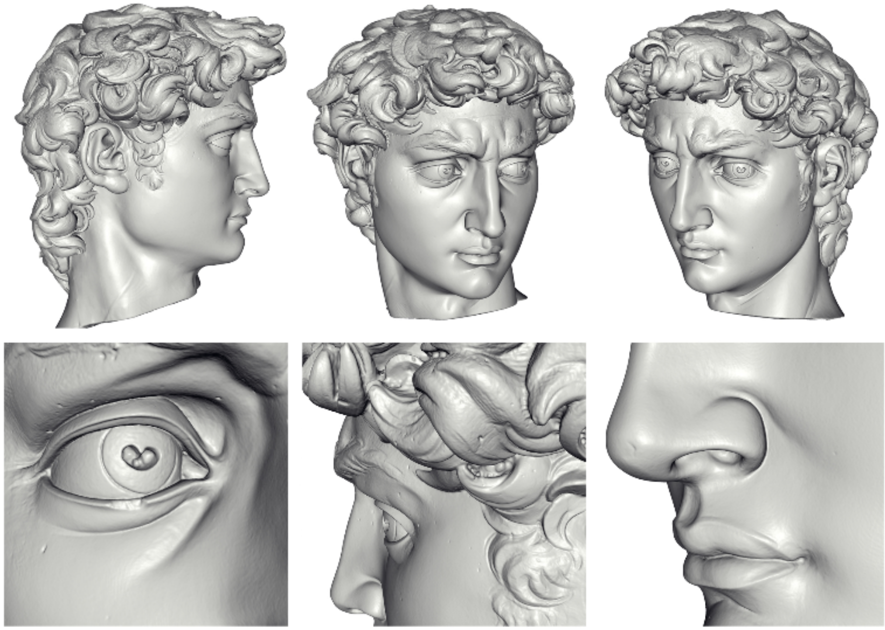
Poisson surface reconstruction

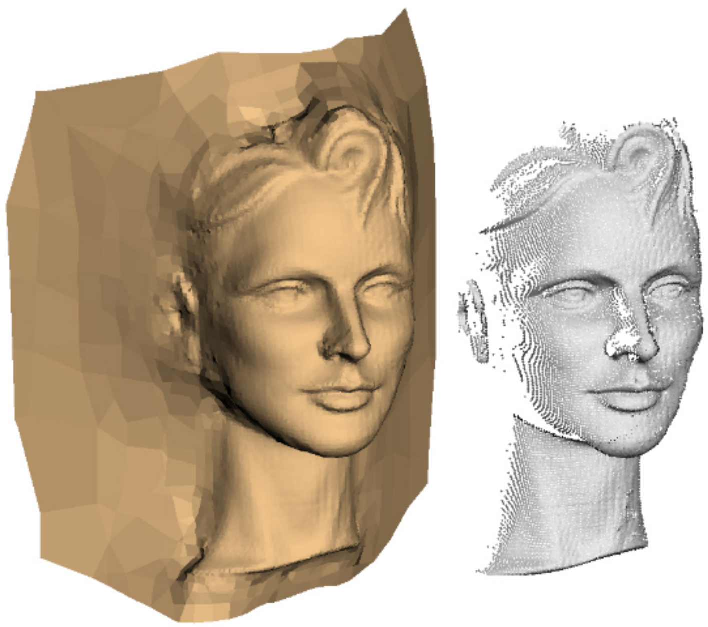
Kazhdan, Bolitho, Hoppe 2006

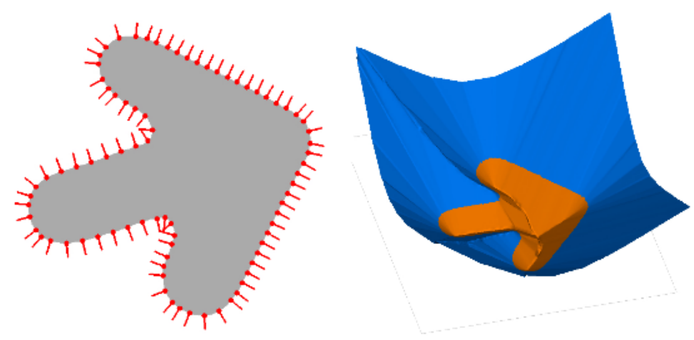


- Solve differential equation to obtain volumetric indicator function from point clouds

SSD: Smooth signed distance surface reconstruction

Calakli, Taubin 2011

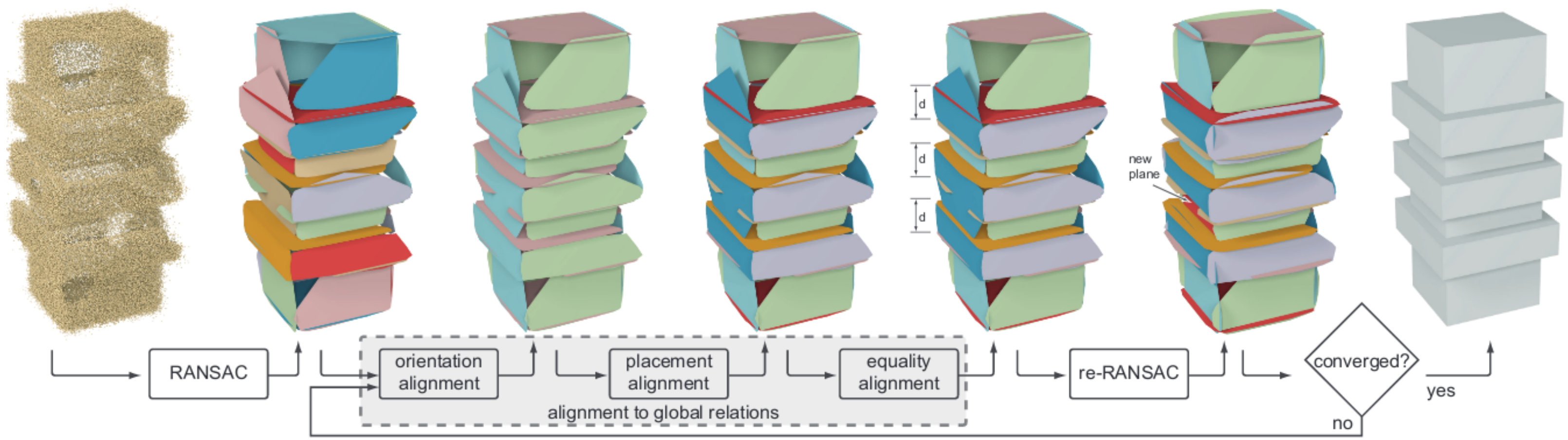




- Solve differential equation to obtain volumetric signed distance field from point clouds

Globfit: Consistently fitting primitives by discovering global relations

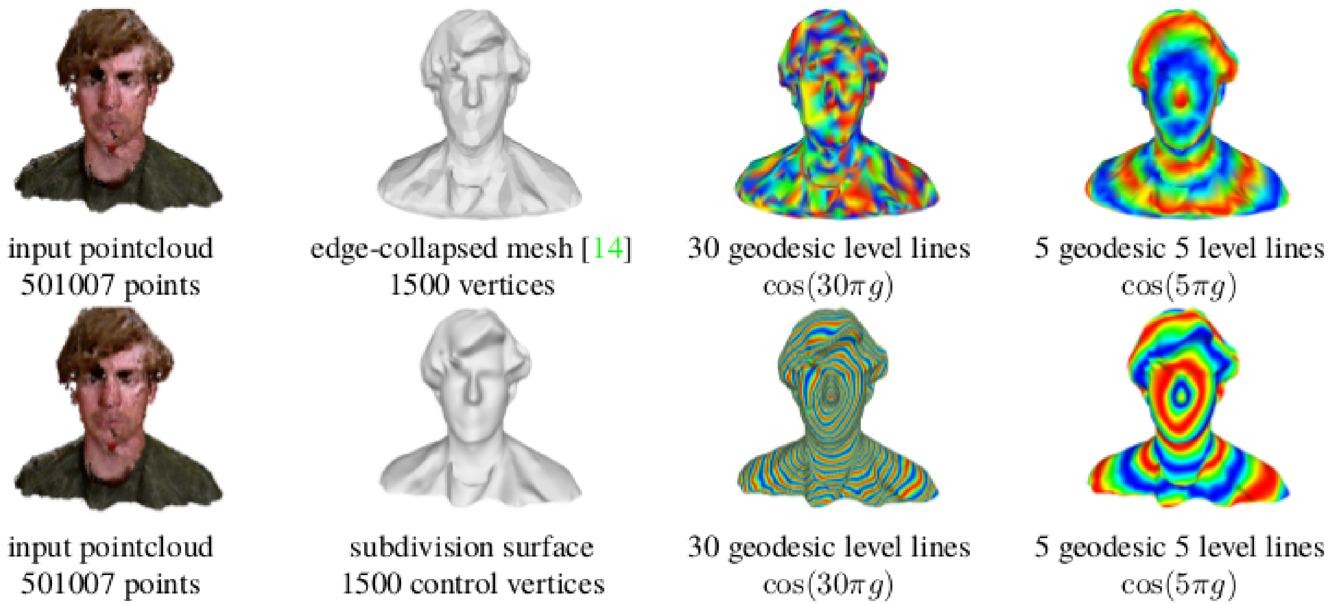
Li, Wu, Chrysathou, Sharf, Cohen-Or, Mitra 2011



- Detect geometric primitives using RANSAC
- Align primitive orientation and location to get more consistent reconstruction

Robust Fitting of Subdivision Surfaces for Smooth Shape Analysis

Estellers, Schmidt, Cremers 2018



- Reconstruct surfaces using subdivision surface representation
- Can compute differential properties on the surface

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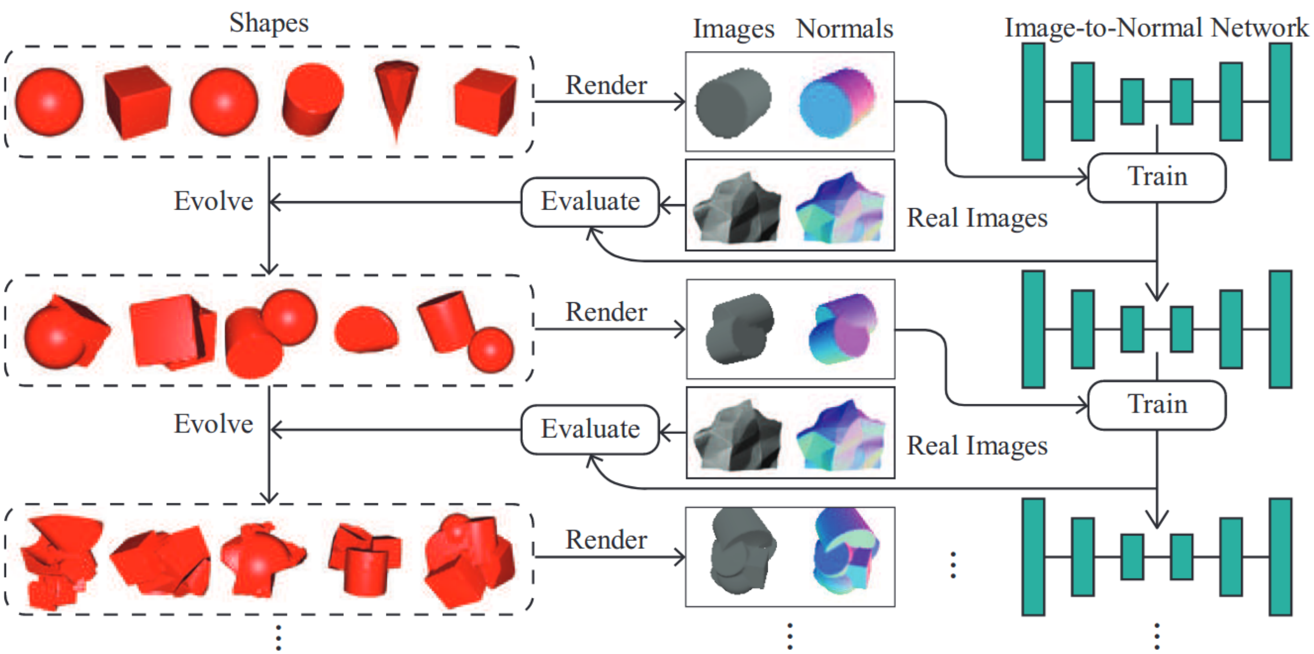
Shape from Shading through Shape Evolution

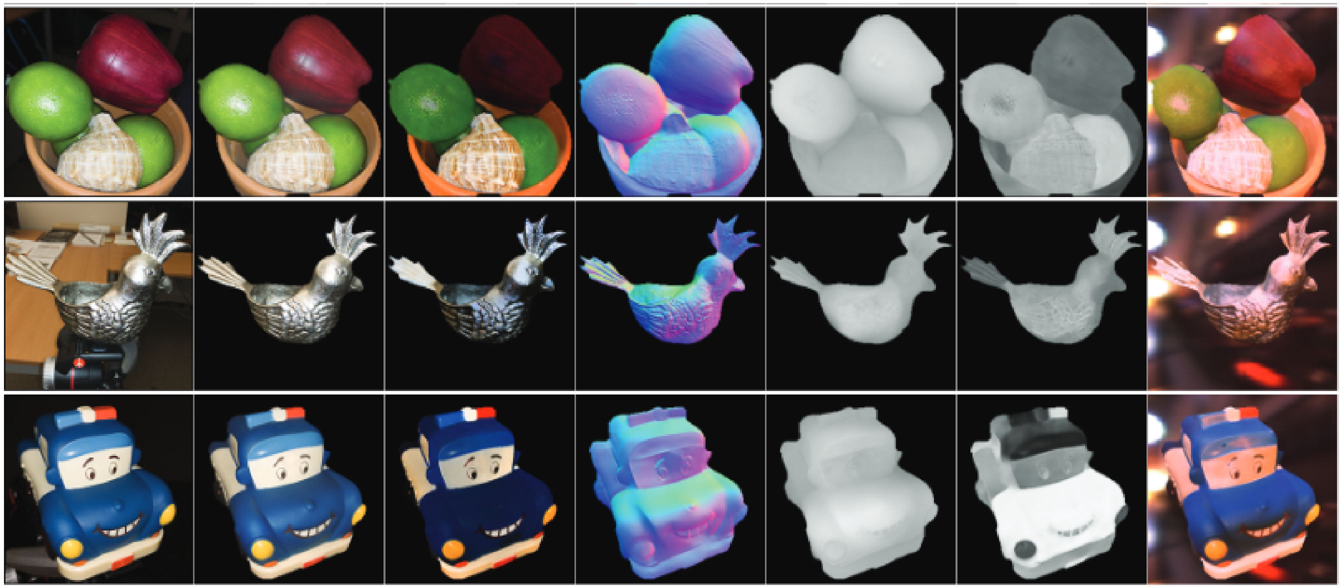
Yang, Deng 2018



- Generate synthetic shapes by primitive evolution
- Use evolved shape to train network for shape-from-shading

Learning to Reconstruct Shape and Spatially-Varying Reflectance from a Single Image

Li, Xu, Ramamoorthi, Sunkavalli, Chandraker 2018



- Inverse rendering using neural network architecture
- Only use a single image to infer object properties

Questions?

Reminder:

The Evolution of Motion Estimation and Real-time 3D Reconstruction

- Web page: `vision.in.tum.de/teaching/ws2019/seminar_realtime3d`
- Password: `realtime3d-ws19`
- Contact: `realtime3d-ws19@vision.in.tum.de`

An Overview of Methods for Accurate Geometry Reconstruction

- Web page: `vision.in.tum.de/teaching/ws2019/seminar_3dgeometry`
- Password: `3dgeometry-ws19`
- Contact: `3dgeometry-ws19@vision.in.tum.de`