3D Scanning & Motion Capture

Introduction

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M. Sc. Lukas Höllein, M. Sc. Andrei Burov, M. Sc. Artem Sevastopolsky

Team

Lecturers

Prof. Matthias Nießner

Teaching Assistants

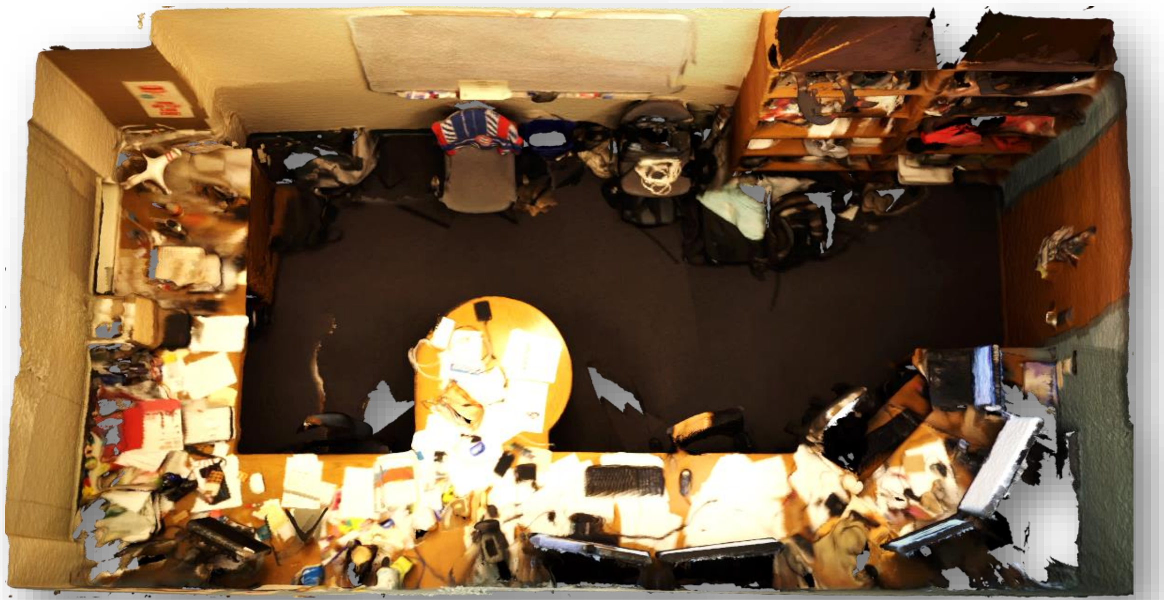
Lukas Höllein

Andrei Burov

Artem Sevastopolsky

Current Research

- 3D understanding of real-world environments



[Dai et al ‘17] BundleFusion

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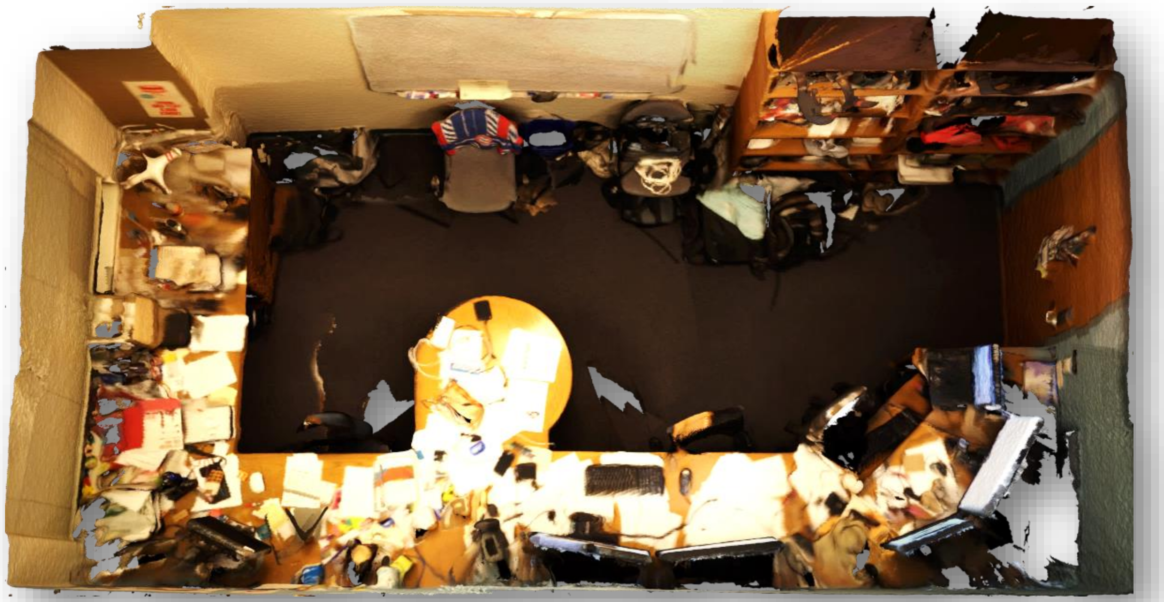

[Dai et al ‘17] BundleFusion

[Dai et al ‘18] ScanComplete

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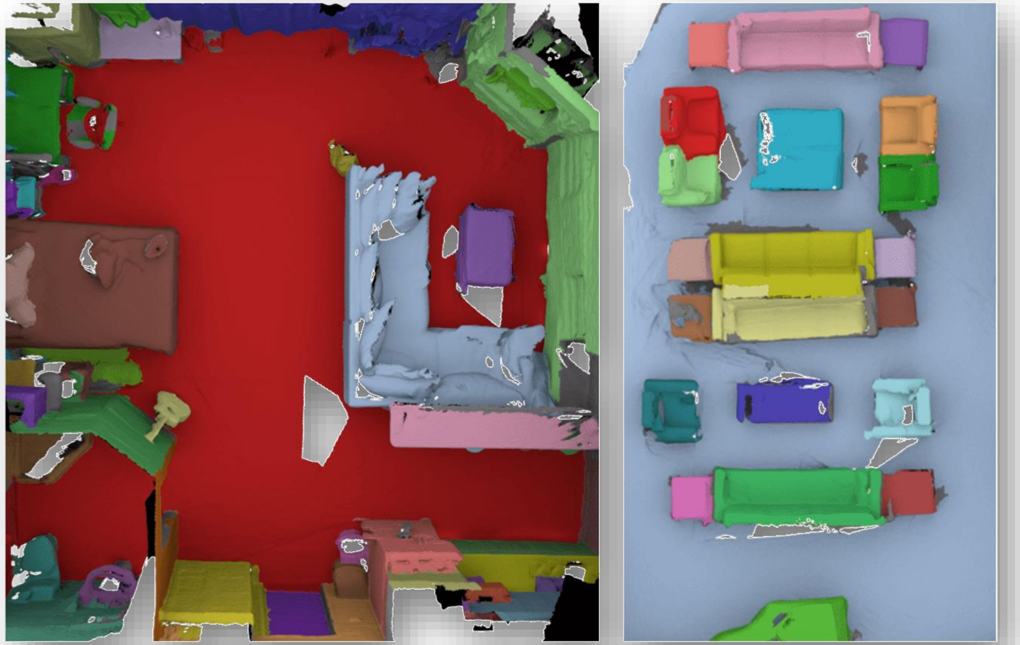

[Dai et al '17] ScanNet

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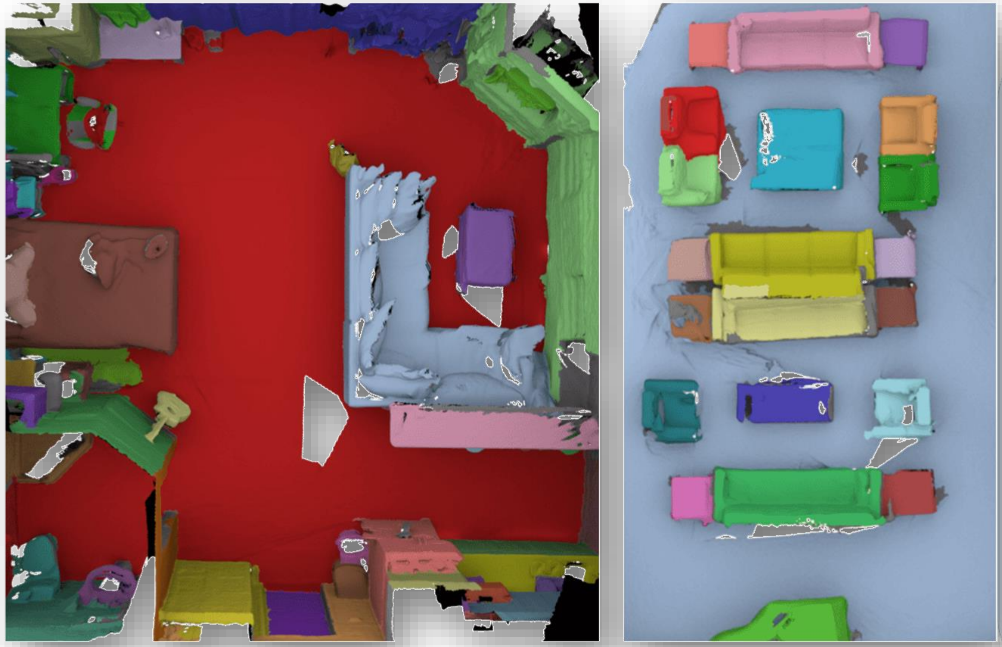
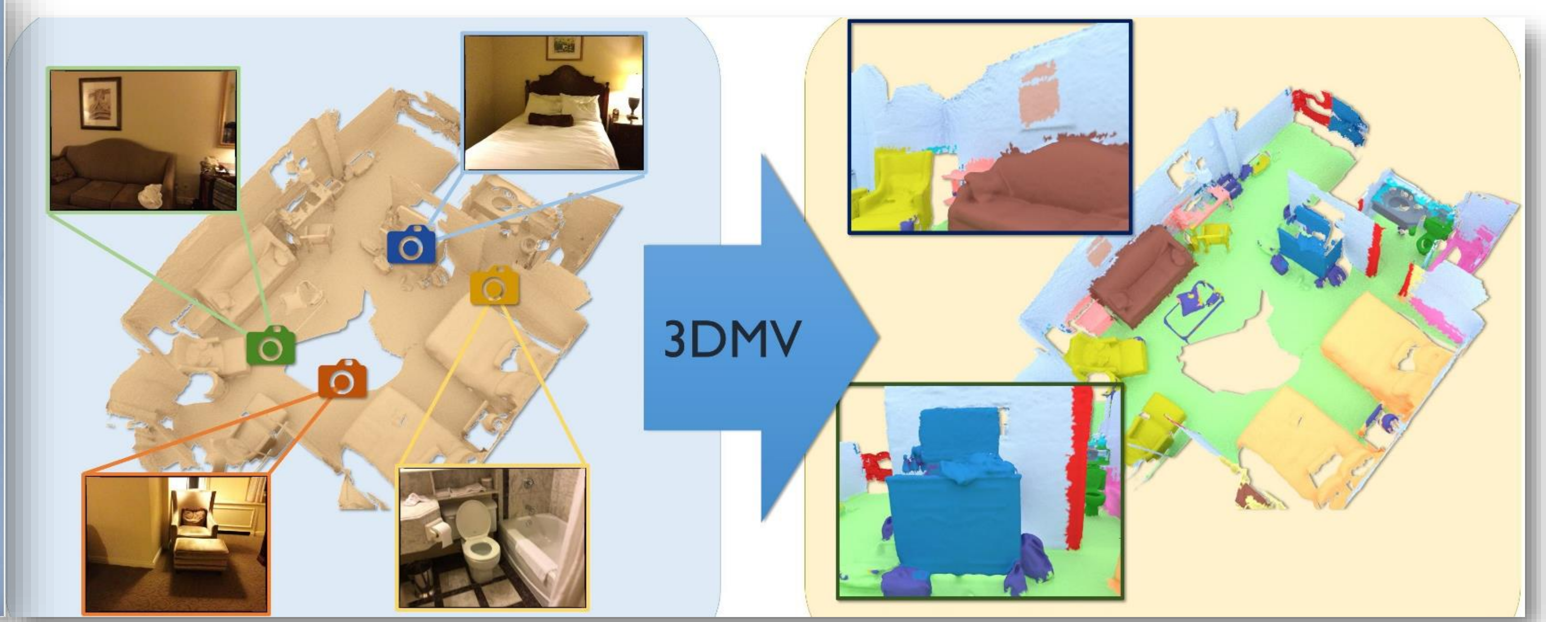


[Dai et al ‘17] ScanNet



[Dai et al ‘18] 3DMV

Current Research

- 3D understanding of real-world environments

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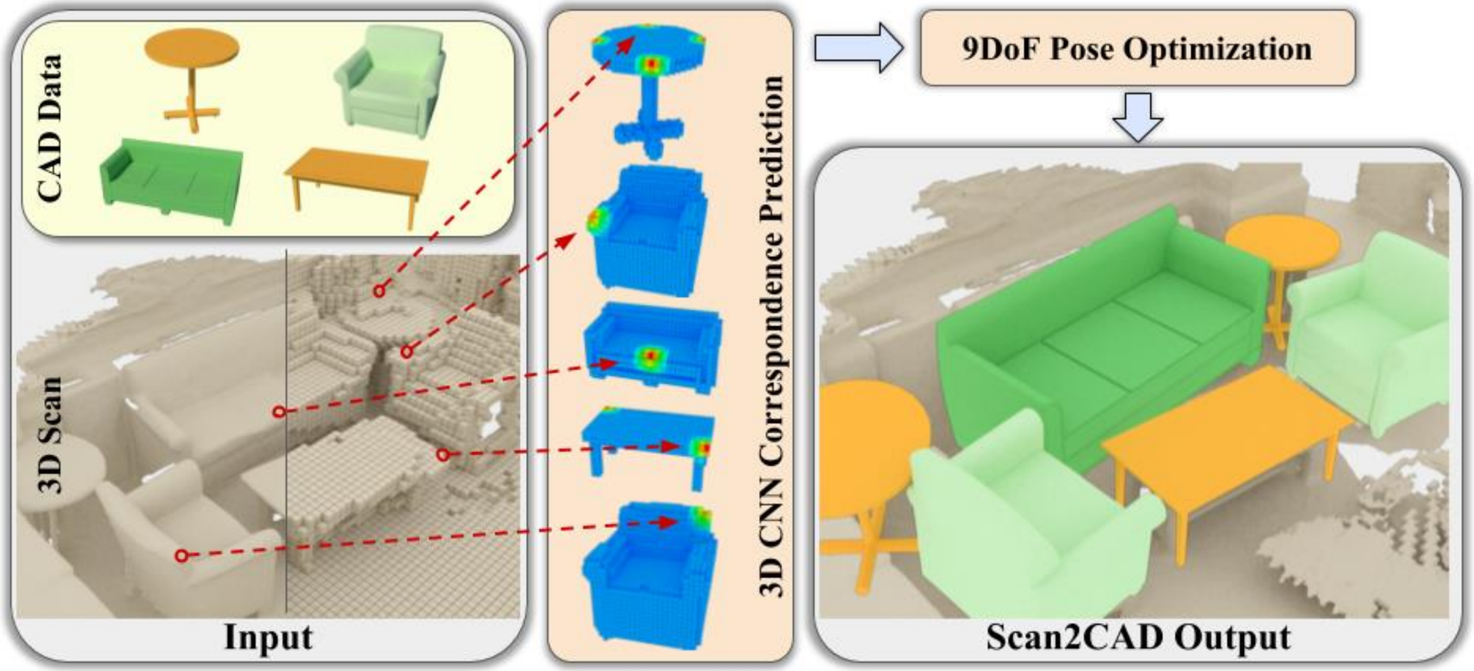


[Avetisyan et al '19] Scan2CAD

High-level Goals

We want to digitize the real world

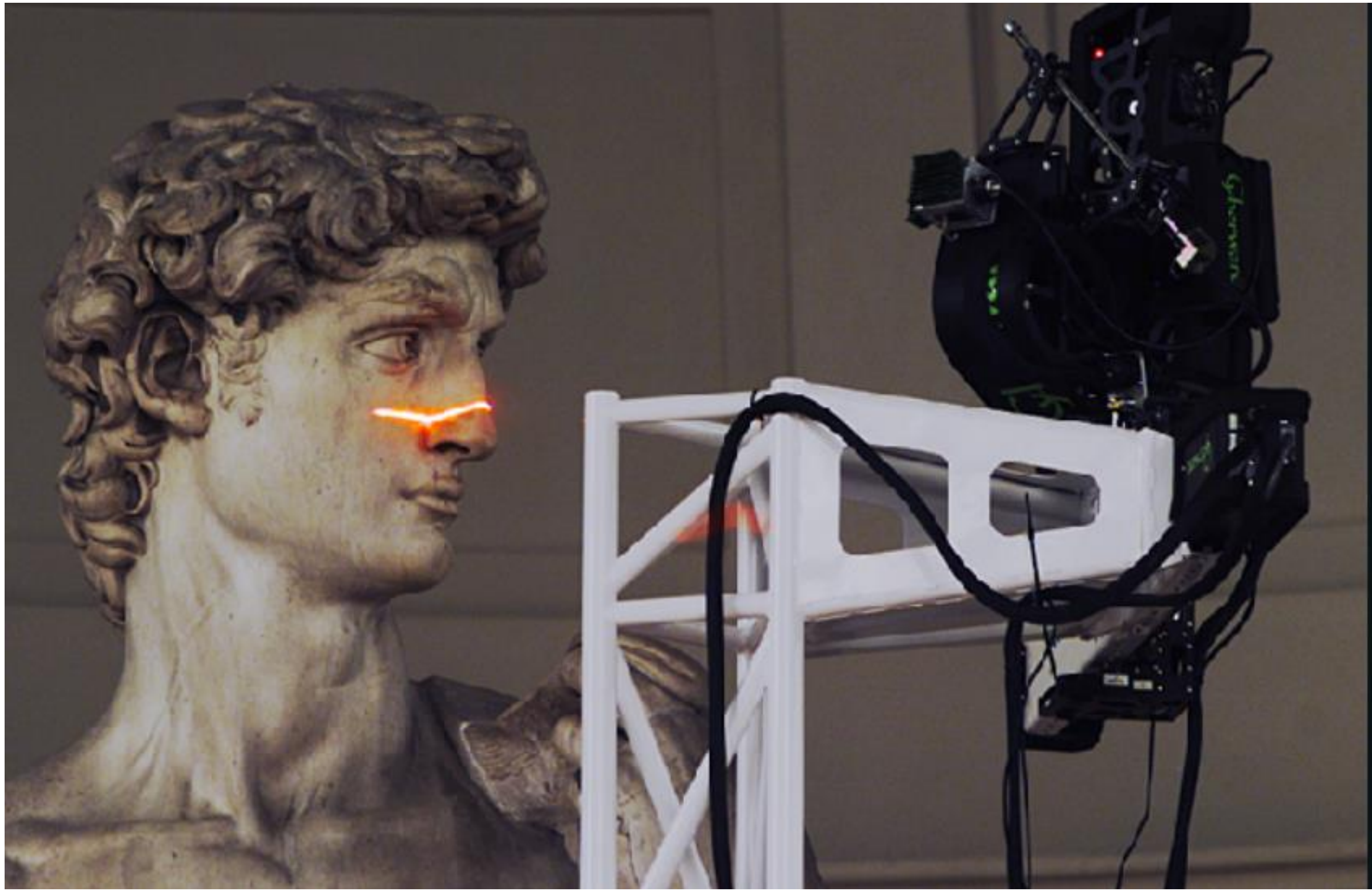
- For future technologies: Virtual- and Augmented Reality
- At the intersection of vision, graphics, and machine learning

- We often use RGB-D sensors (e.g., the Microsoft Kinect)
- Ultimately, we want use only webcams and phones
- Augment the content creation pipeline!

High-level Goals

- Static 3D reconstruction vs dynamic reconstruction
- Movies vs games
- High-end scanners vs low-end scanners
- Real-time vs offline

Capturing 3D Geometry



Digital Michelangelo Project [Levoy et al. 00]

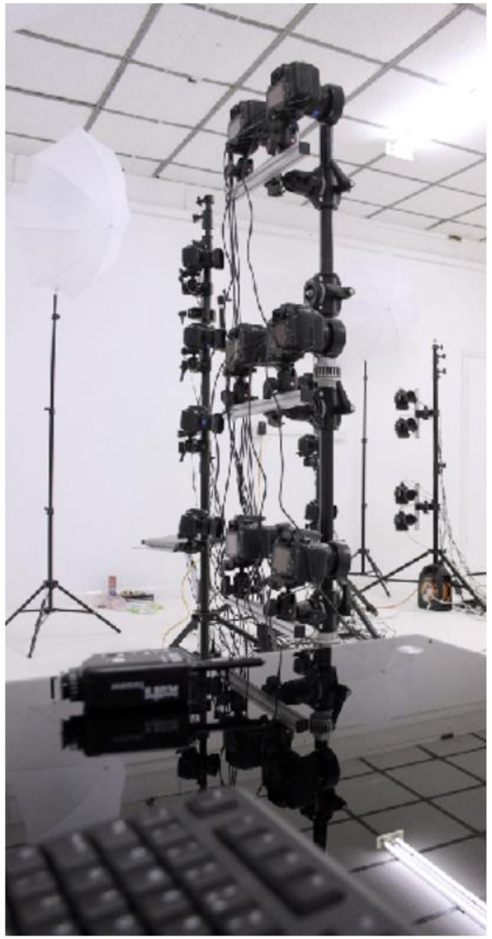
Online Reconstruction

First real-time work [Rusinkiewicz et al. 02]

Large Scale Capture

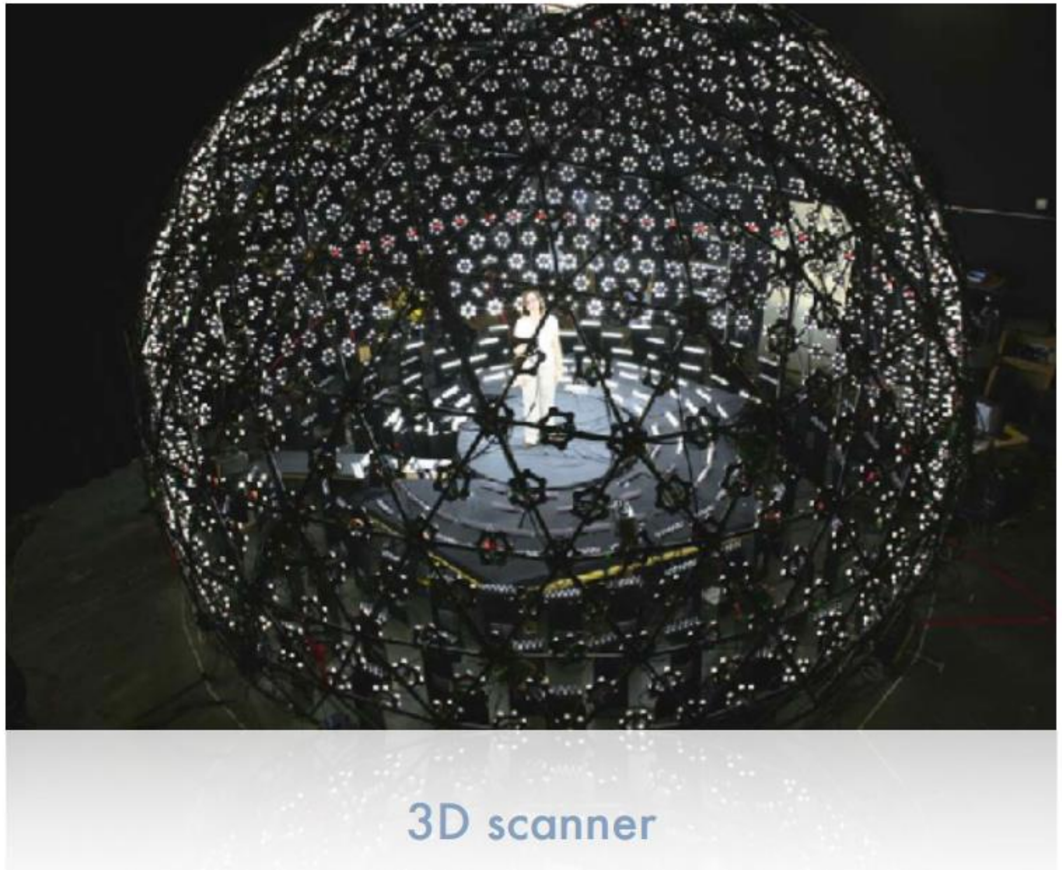
Slide Hao Li

Multi-view Stereo



Lee Perry-Smith, Infinite Realities + Agisoft / Slide Hao Li

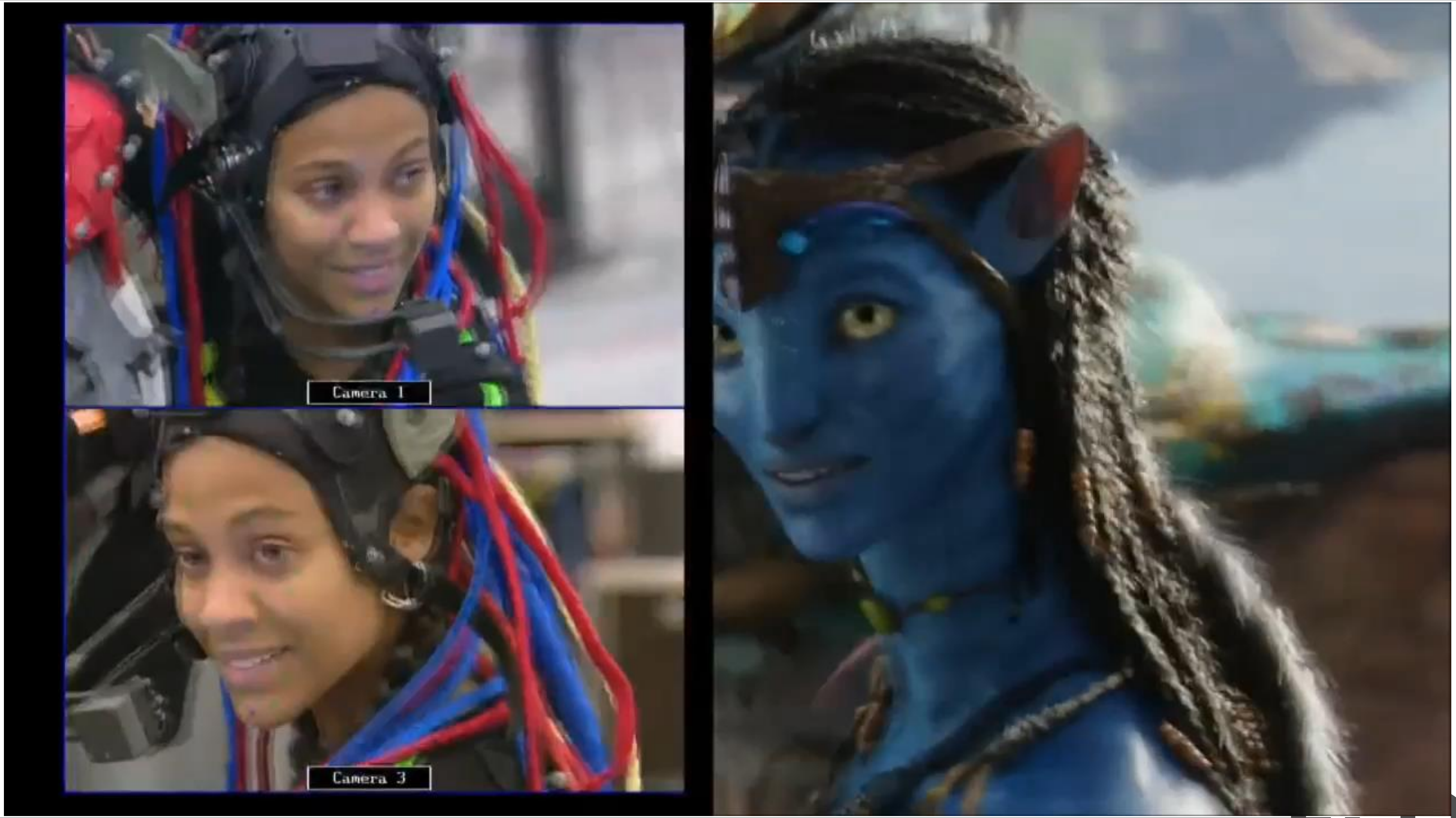
USC Light Stage: Fully Body Scanner



Slide Hao Li

Motion Capture in Movies

Motion Capture in Movies



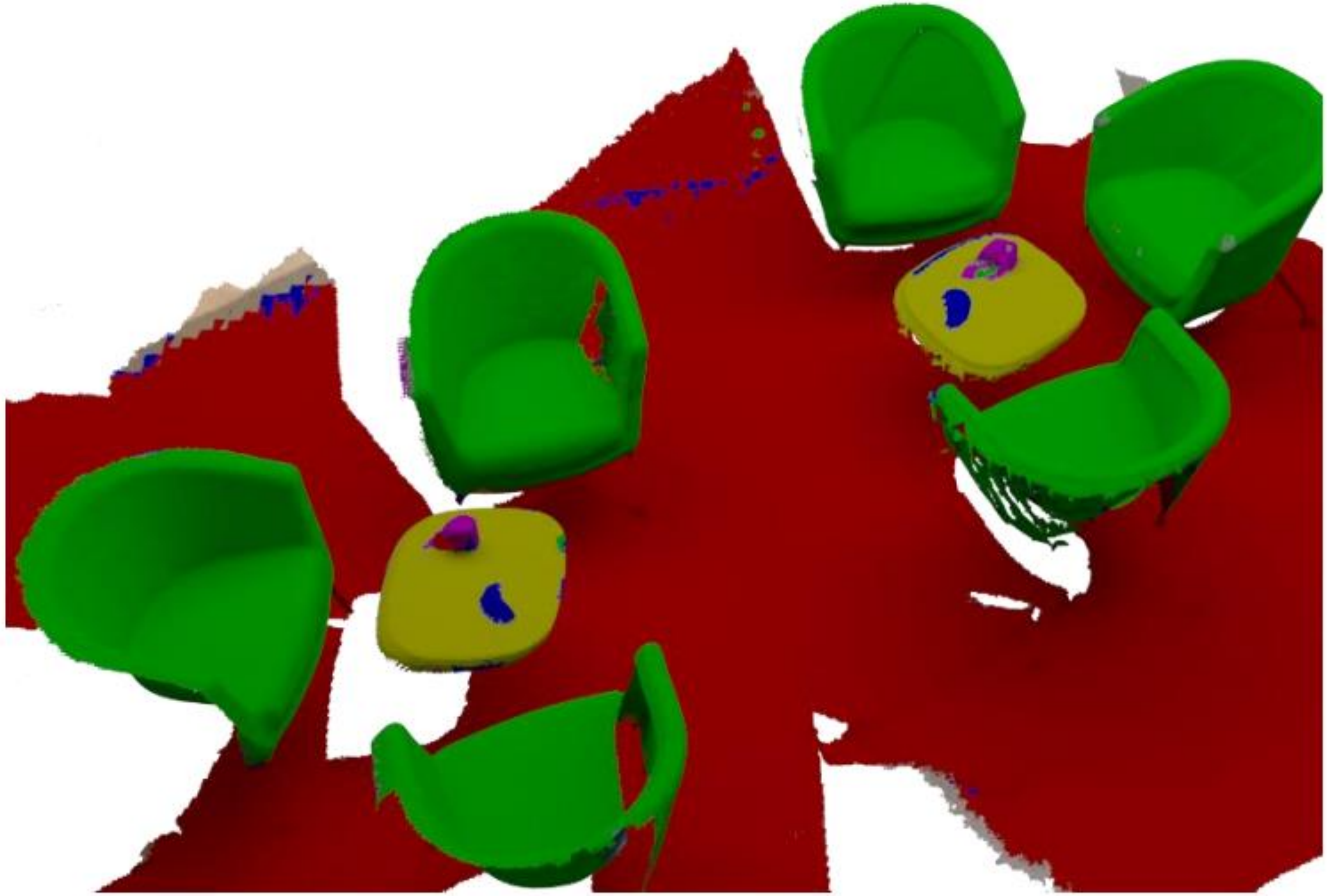
Capturing geometry

Source: matterport.com

Capturing geometry

Source: matterport.com

Scene understanding



Personal avatars

Digitalized content

Source: microsoft.com

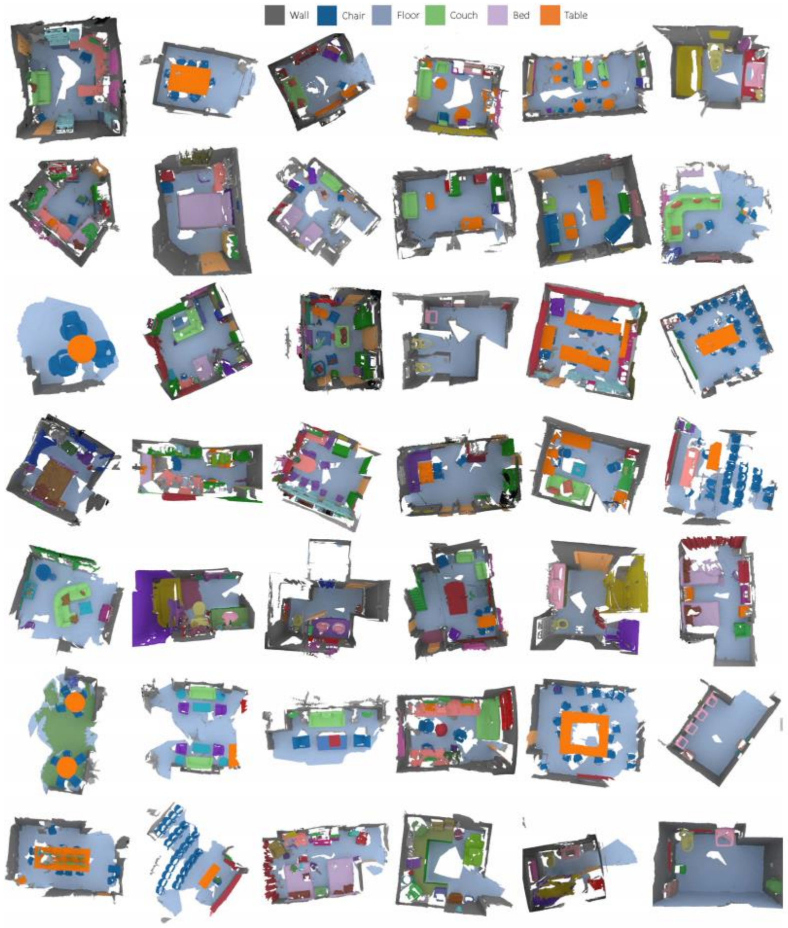
Digitalized content

BundleFusion

[Dai et al ‘17] BundleFusion

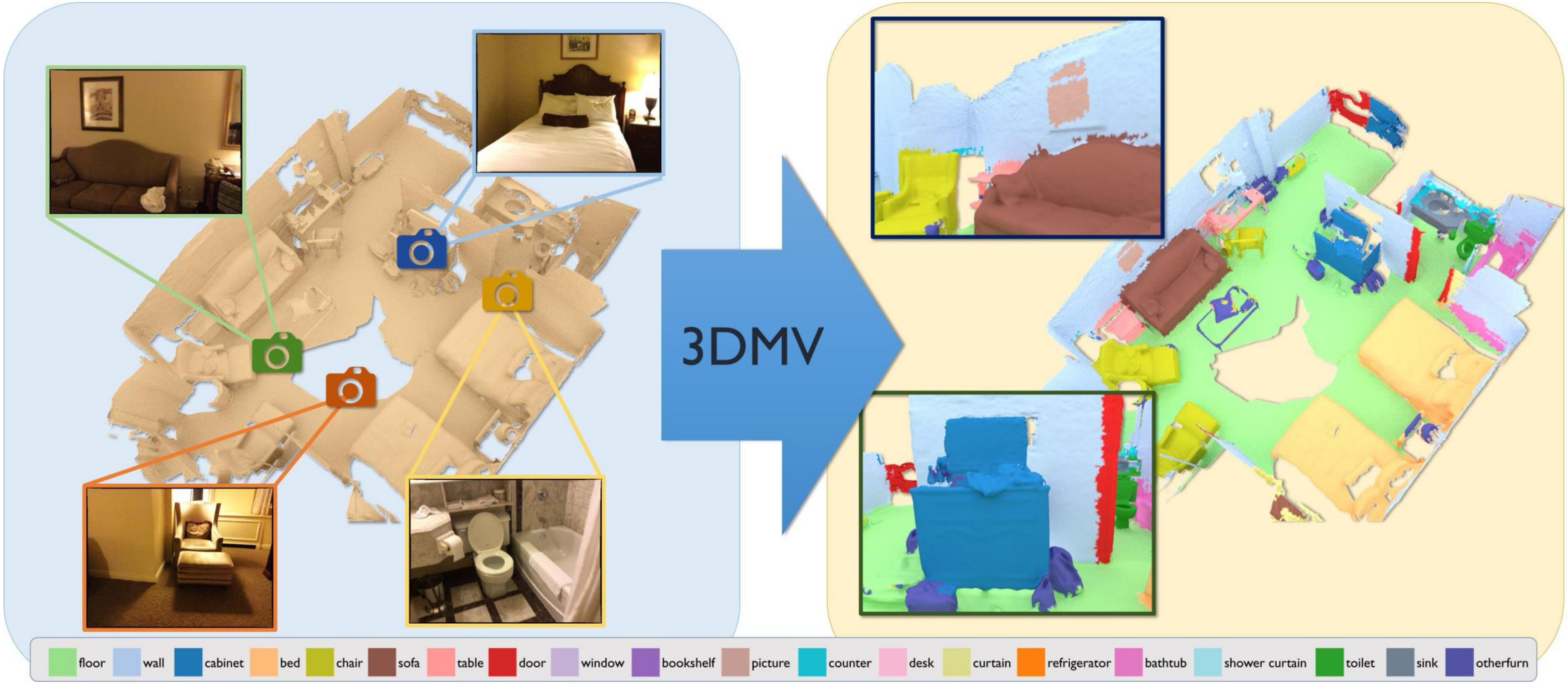
BundleFusion

ScanNet



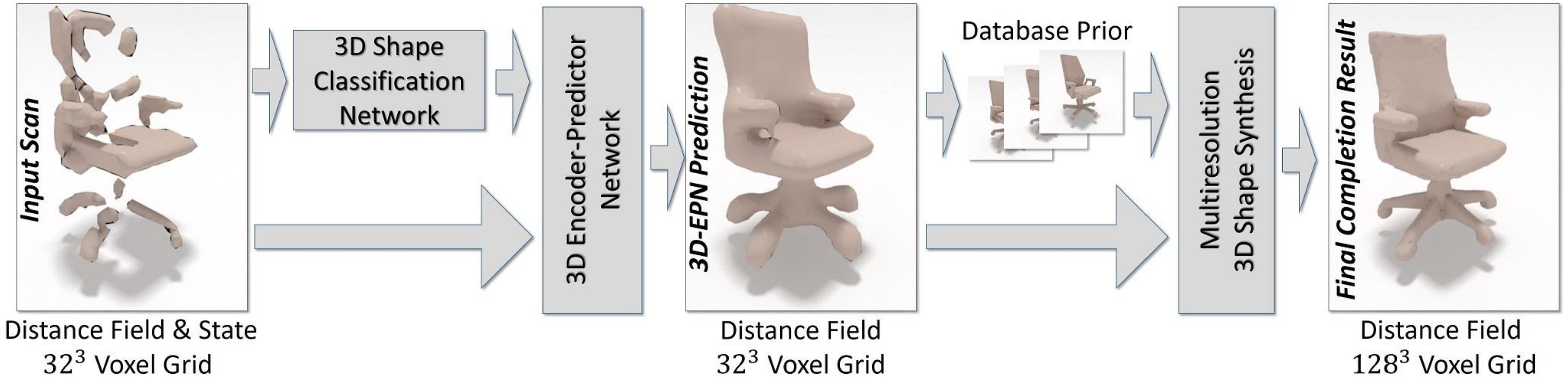
[Dai et al ‘17] ScanNet

3DMV



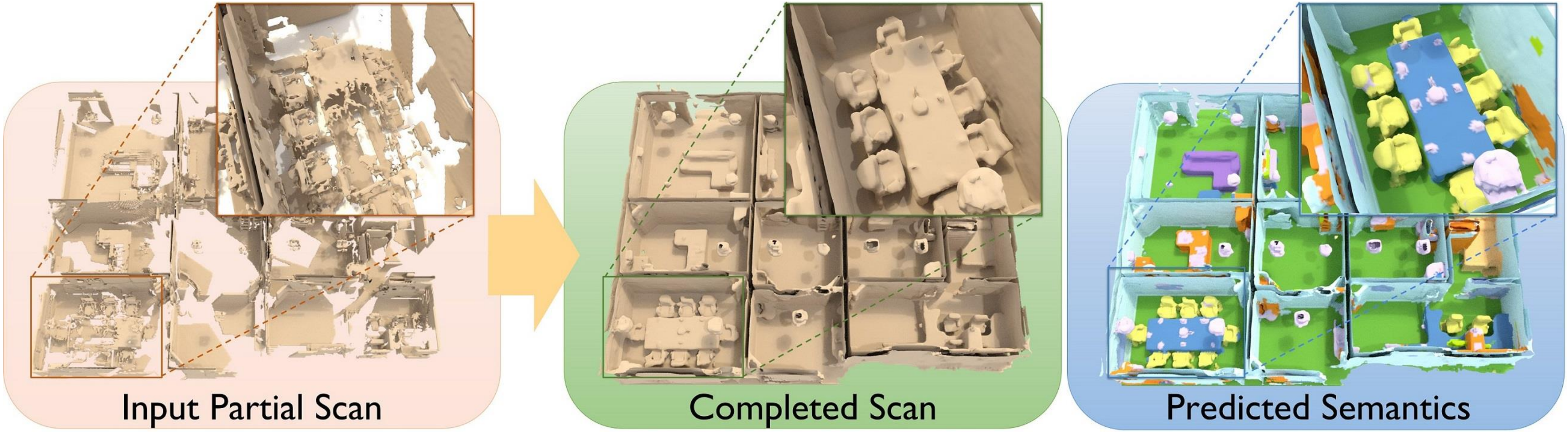
[Dai et al '18] 3DMV

Shape Completion



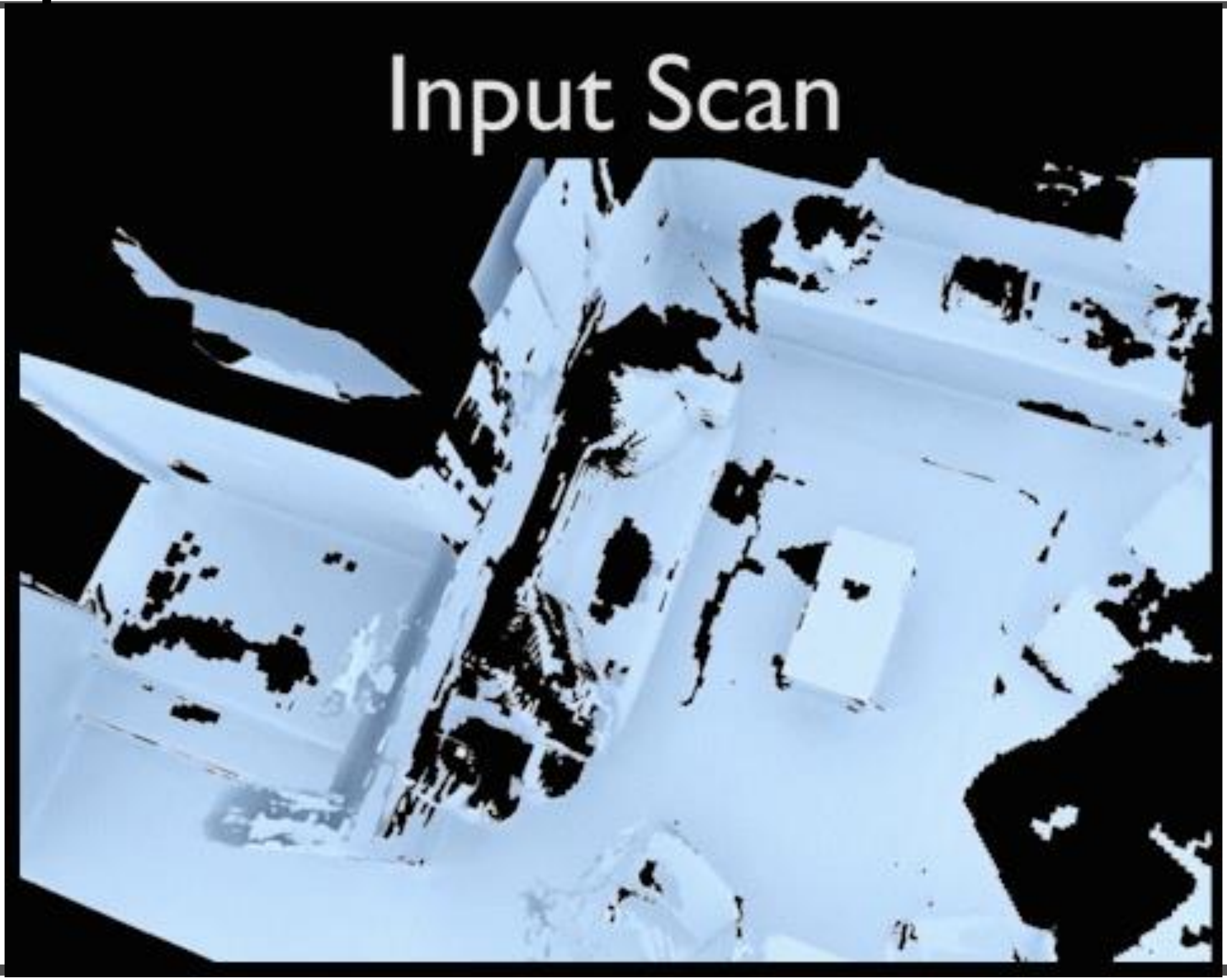
[Dai et al '17] 3D-EPN

Scene Completion



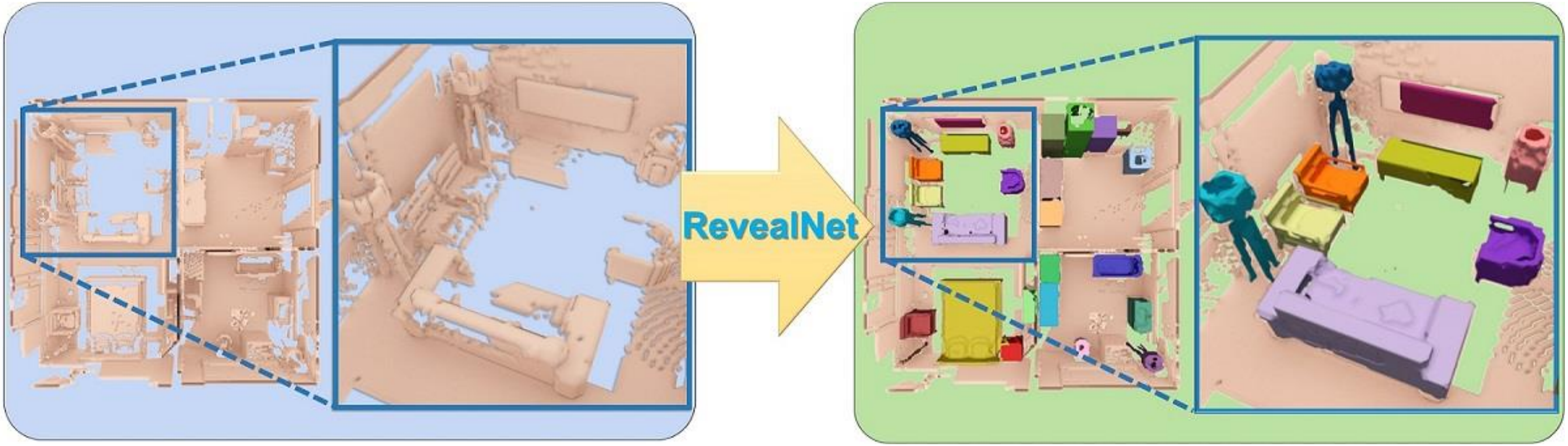
[Dai et al '18] ScanComplete

Scene Completion



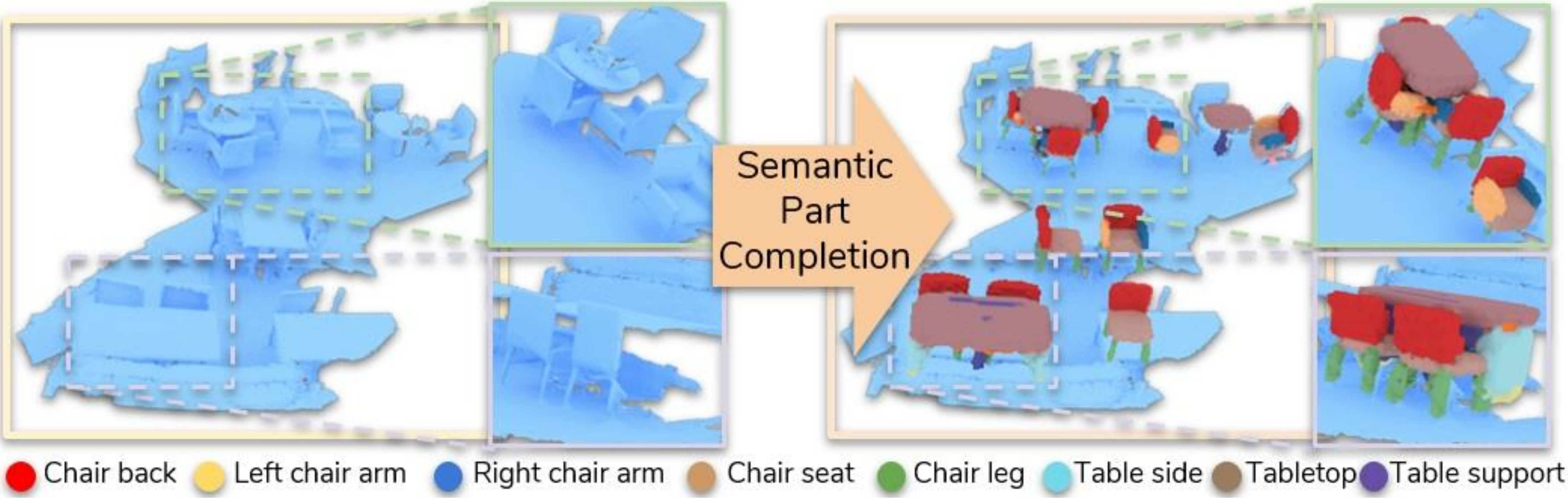
[Dai et al '20] SG-NN

3D Semantic Instance Completion



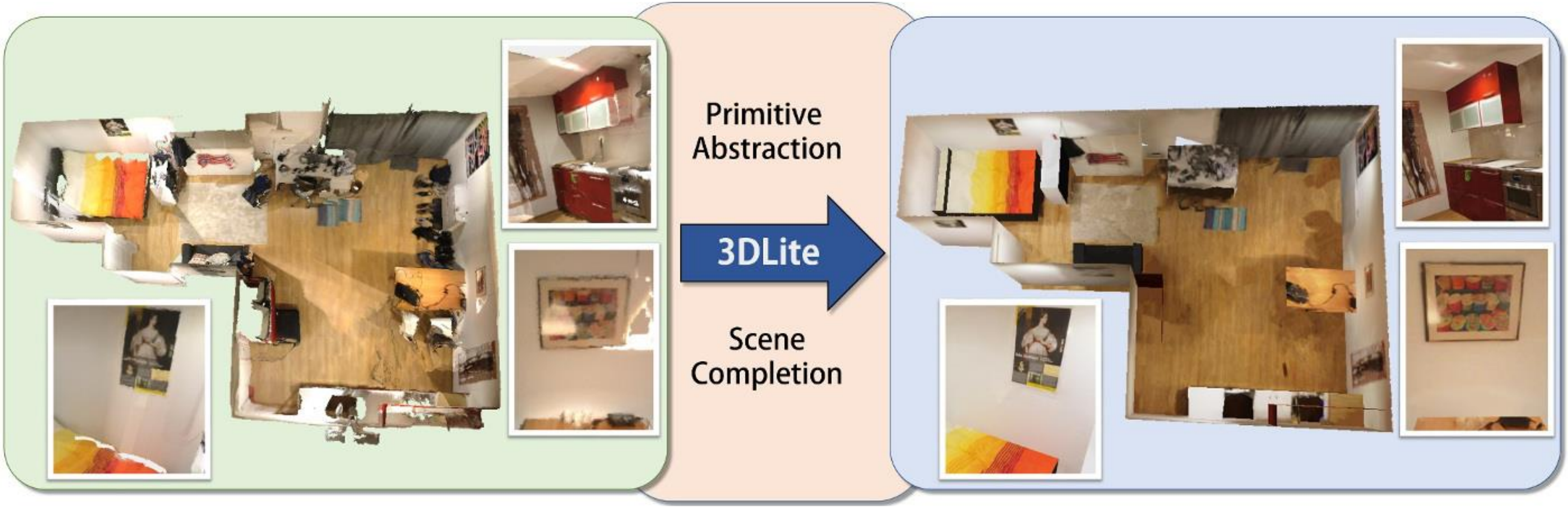
[Hou et al ‘20] RevealNet

Part-based Understanding of 3D Scans



[Bokhovkin et al '21] Towards Part-Based Understanding of RGB-D Scans

Capturing Colors and Textures



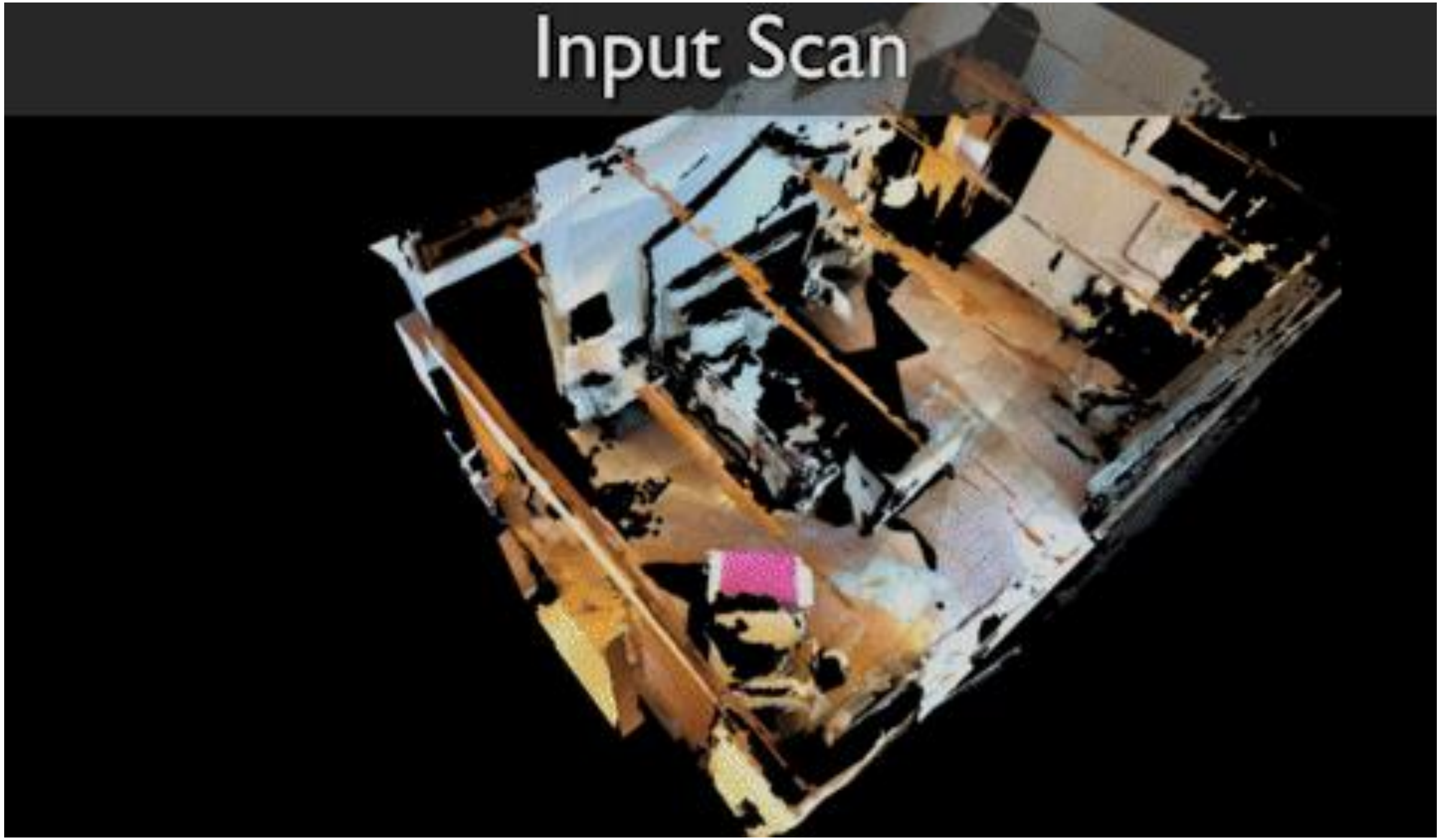
[Huang et al ‘17] 3DLite

Capturing Colors and Textures

Input Image Geometry Our Reconstructed Textured Model Zhou and Koltun Ours

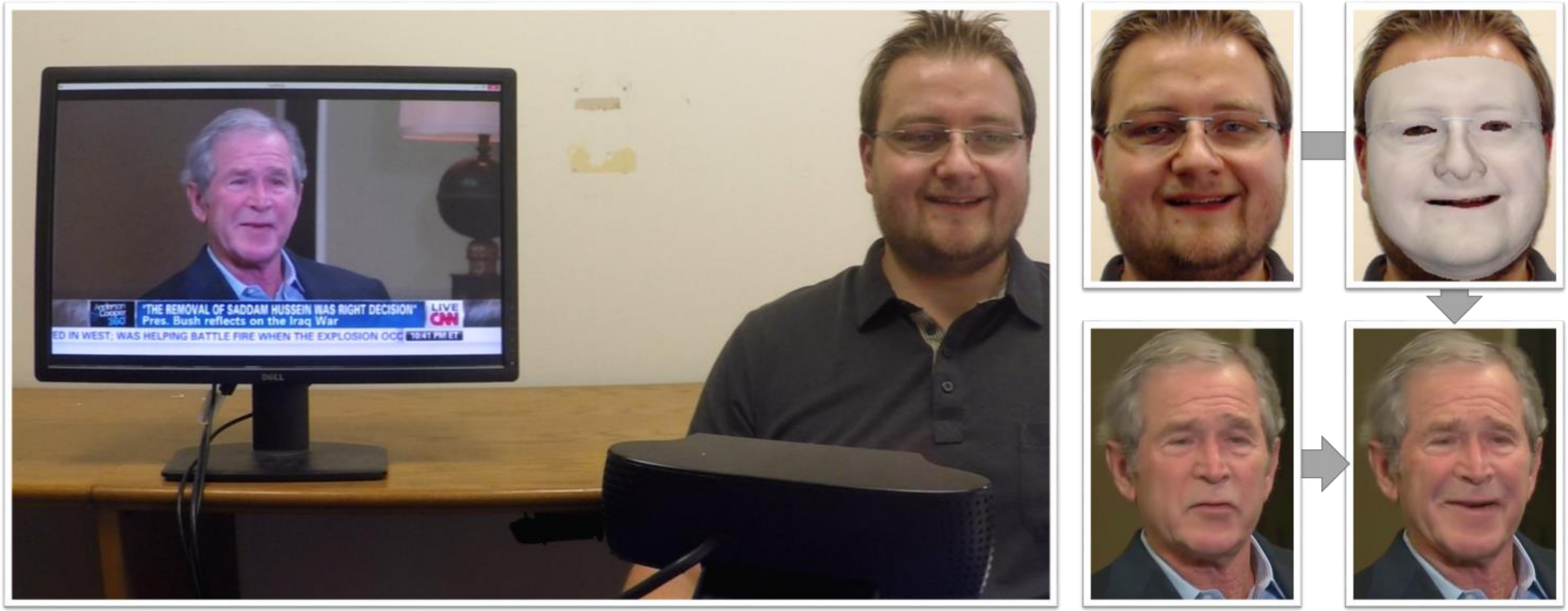
[Huang et al '20] Adversarial Texture Optimization

Capturing Colors and Textures



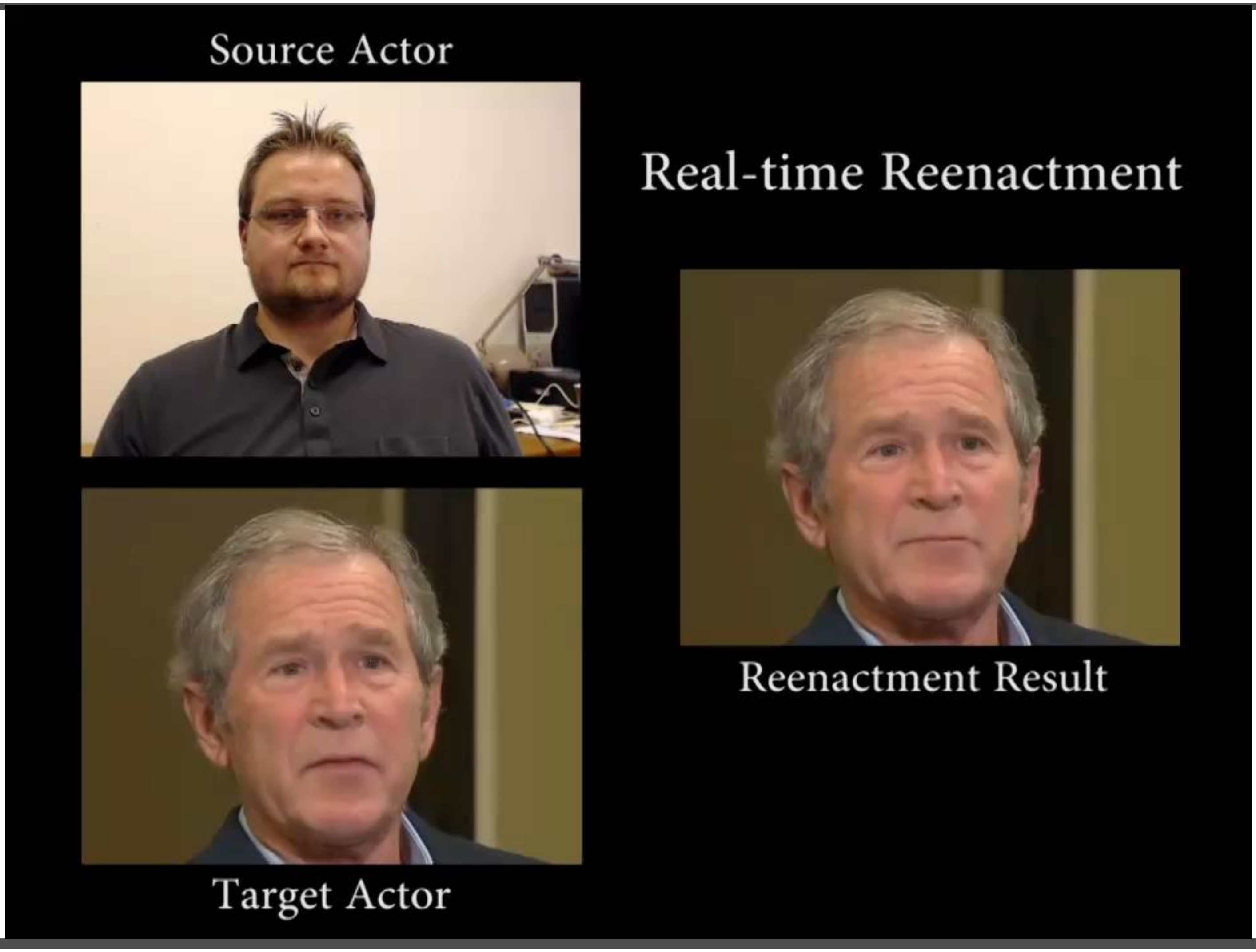
[Dai et al '21] SPSG

Face2Face



[Thies et al '16] Face2Face

Face2Face

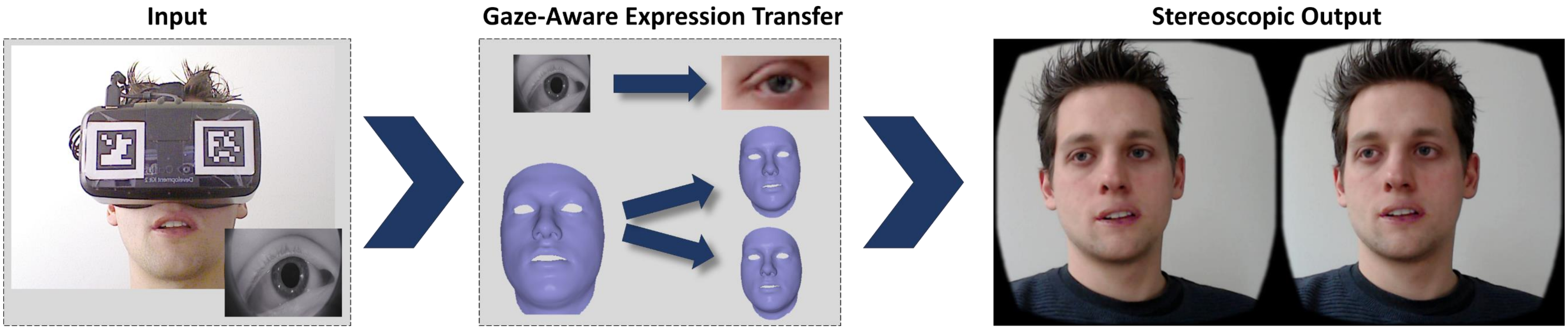


[Thies et al ‘16] Face2Face

IMU2Face


IMU2Face: Real-time Gesture-driven
Facial Reenactment
Justus Thies[1] Michael Zollhöfer[2]
Matthias Nießner[1]
[1]Technical University of Munich
[2]Stanford University
First 100 Days
FACE THE NATION

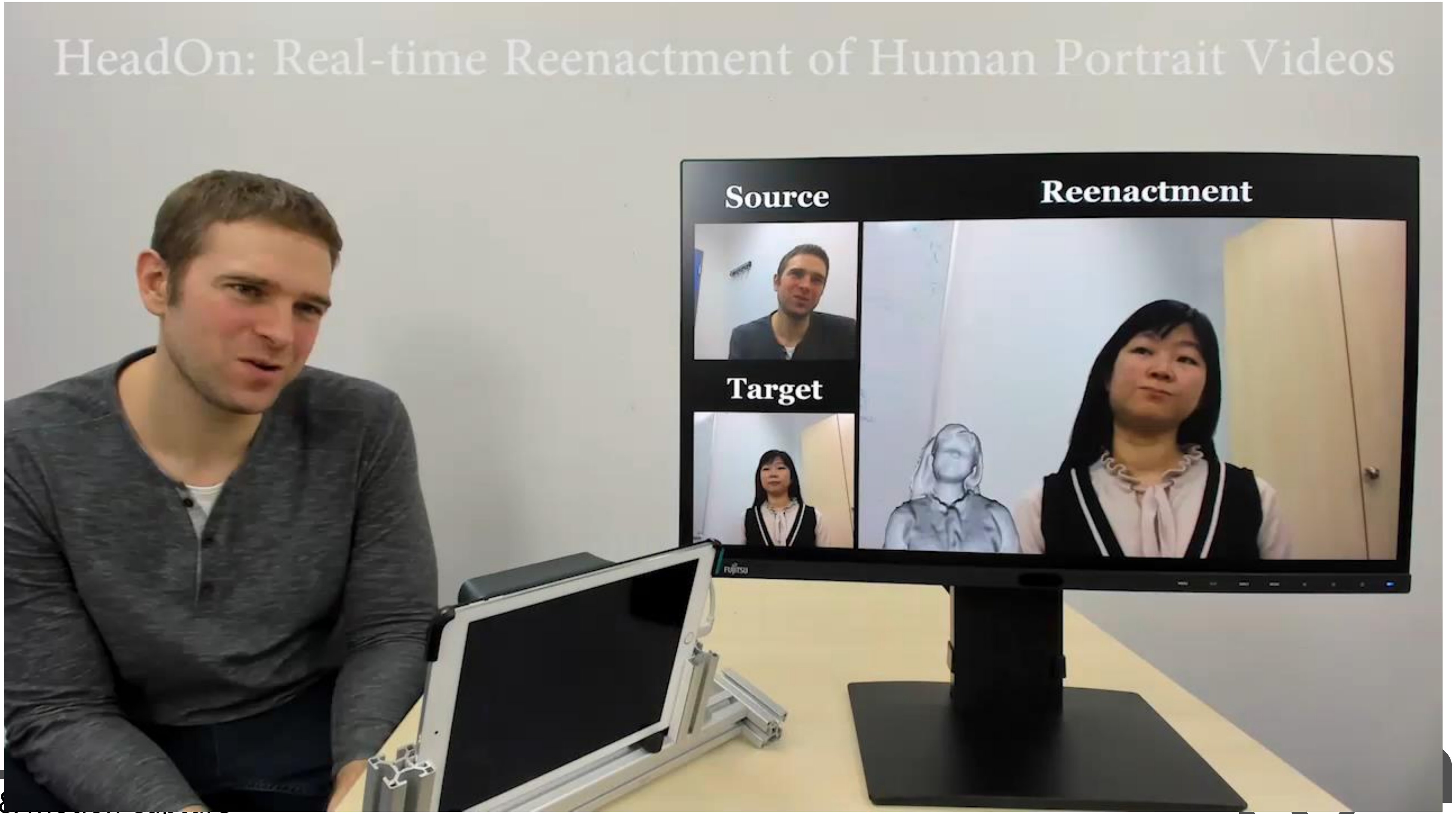
FaceVR: Self-Reenactment for HMD Removal



[Thies et al ‘18] FaceVR

FaceVR: Self-Reenactment for HMD Removal

HeadOn: Real-time Reenactment Human Portraits

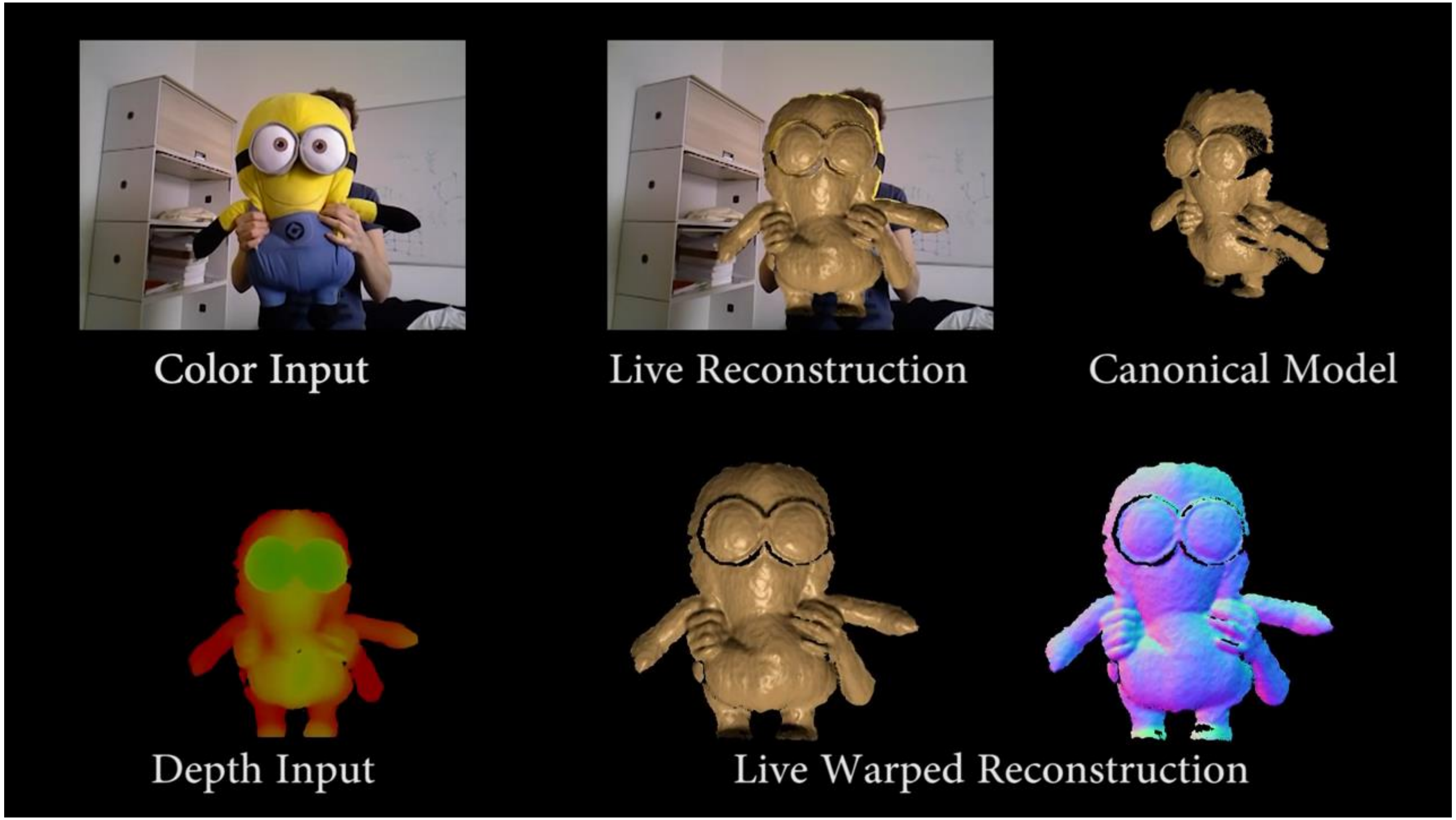


[Thies et al '18] HeadOn

VolumeDeform

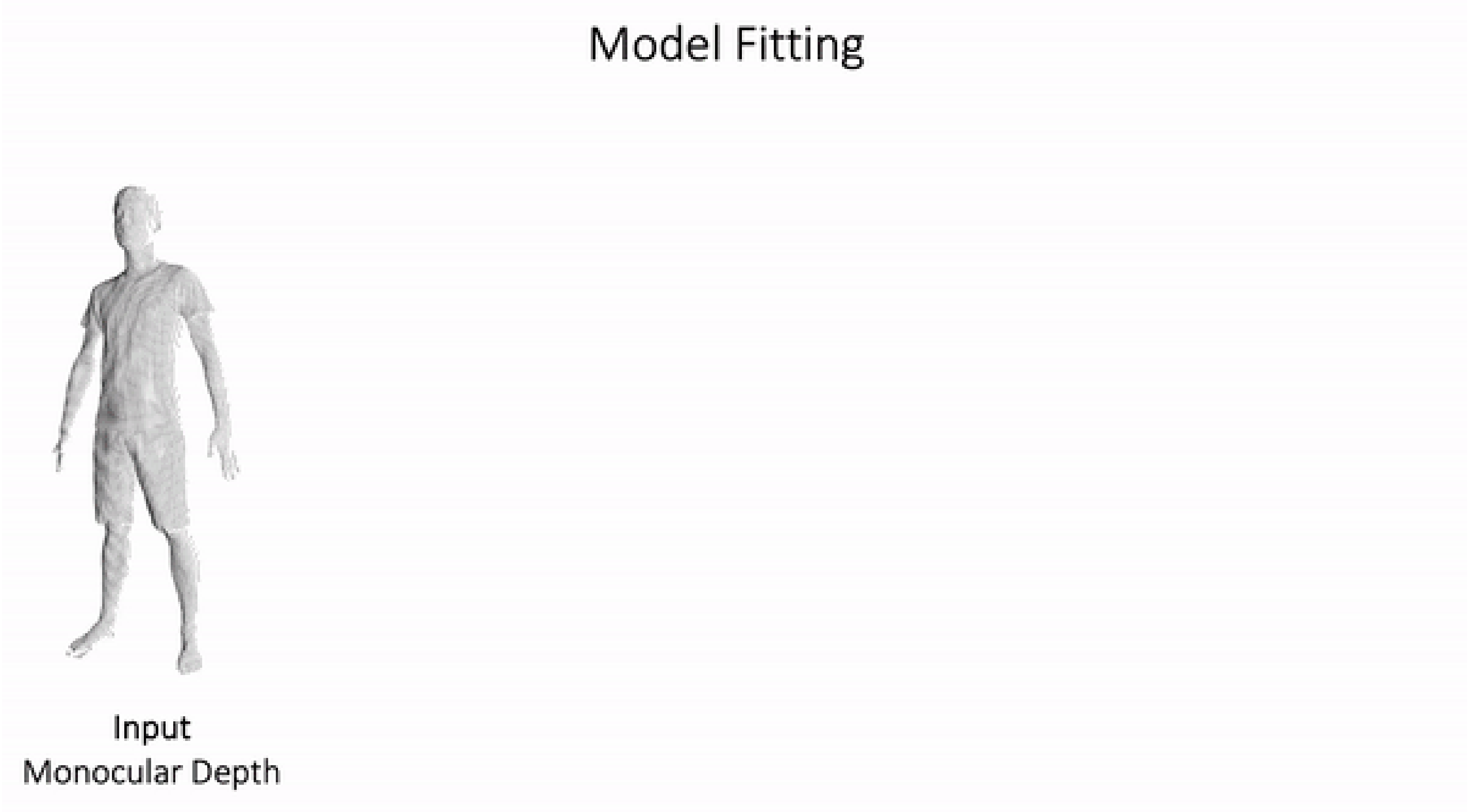
[Innmann et al '16] VolumeDeform

VolumeDeform



[Innmann et al '16] VolumeDeform

Neural Parametric Models for 3D Deformable Shapes



[Palafox et al '21] NPMs

Holoportation

Source: microsoft.com

Novel View Synthesis / Neural Radiance Fields

[Mildenhall et al. ‘20] NeRF

Face/Head Reconstruction

Input Video

4D Head Avatar

[Grassal et al. ‘22] Neural Head Avatars

Preliminary Topics of the Lecture

- 1. Lecture – Basic Concepts of Geometry
- 2. Lecture – Surface Representations
- 3. Lecture – Overview of Reconstruction Methods
- 4. Lecture – Non-linear Optimization
- 5. Lecture – Rigid Surface Tracking & Reconstruction

Preliminary Topics of the Lecture

- 6. Lecture – Deformation and Non-rigid Surface Tracking
- 7. Lecture – Non-rigid Tracking & Reconstruction
- 8. Lecture – Face Tracking & Reconstruction
- 9. Lecture – Body & Hand Tracking
- 10. Lecture – Lighting and Materials
- 11. Lecture – Novel View Synthesis / Neural Rendering

Lecture+Tutorials

- Requirements
  - C++ is a must
  - Profound knowledge of linear algebra
  - Basic concepts of 3D graphics

Lecture+Tutorials

- Lecture: Online videos
  - Lecture content (theory)
- Live Q&A for Lectures: 30 min, during lecture timeslot via Zoom
- Tutorials:
  - Uploaded with lectures
  - Help on exercises and projects
- Office Hours:
  - Contact TAs for zoom appointments
  - Use Moodle!

Exercises - Organization

Part 1: Tutorials & Exercises

Apr 26 - Jun 10

- Implement basic concepts
- Learning by doing
- Code in C++

Part 2: Final Project

Jun 10 - Jul 29

- 3D reconstruction / tracking
  - KinectFusion
  - Face Fitting
  - Bundling
  - ...

Question/Problems → Ask in Moodle; schedule Zoom/in-person meeting

Exercises - Organization

- **Upload times**
  - Introduction of new exercise (**Fridays**)
  - Submission of new exercise (**Fridays, 23:59**)
  - Solution from previous exercise (**Mondays**)
  - Until start of final projects

6	Fri	Release Exercise 1
7	Sat	
8	Sun	
9	Mon	
10	Tue	Lecture
11	Wed	
12	Thu	
13	Fri	Release Exercise 2 **Exercise 1 Due**
14	Sat	
15	Sun	
16	Mon	Solution to Exercise 1

- **Office Hours**
  - Use the Moodle forum for questions
  - For hard problems:
    - **schedule** a meeting with us via mail
      andrei.burov@tum.de lukas.hoellein@tum.de artem.sevastopolskiy@tum.de
    - Zoom **or** in-person during our office hours, Fridays 14:15-15:45

Exercises - Organization

- 5 small, self-contained exercises
  - **1 week** of working time, **deadline Friday 23:59**
  - **Groups of two** are allowed

- Grade bonus of 0.3
  - Submit all 5 exercises
  - Pass at least 4 exercises, 5th exercise passed/borderline
    - 0-50 (failed), 51-70 (borderline), 71-99 (passed), 100 (perfect pass)
  - Only applicable for passed exams!

Exercises – Preliminary Outline

- Basic 3D reconstruction algorithms
  1. Exercise (Camera Intrinsics, Back-projection, Meshes)
  2. Exercise (Surface Representations, Volumetric Fusion, SDF)
  3. Exercise (Procrustes)
  4. Exercise (Optimization)
  5. Exercise (Object Alignment, ICP)

*see exercise info for more details

Final Project

- Start: Mid-semester
- 3D reconstruction / tracking project
  - KinectFusion, Face Fitting, Bundling etc. …
- 5+ weeks
- Groups of 3-4
- Proposal (abstract 1-2 pages)
- Presentation of the project + abstract (2 pages with results)

Final Exam

- Questions covering lecture content
- Questions regarding final project

- At this point we are *not* yet sure whether exam is in-person or online – we will announce it as soon as things become clear

Logistics

TAs:

- Andrei Burov andrei.burov@tum.de
- Lukas Höllein lukas.hoellein@tum.de
- Artem Sevastopolsky artem.sevastopolskiy@tum.de

Lectures:

- Online Videos + Live Q&A

Tutorials:

- Uploaded with lectures
- Focus on exercises and projects

Office Hours:

- Email TAs for zoom appointments

Exercises:

- In total, 5 exercises with 1-2 weeks each for completion
- All exercises completed (4 of 5 passed, see exercise info for more details) gives **0.3** bonus on final grade
- First exercise: next week
- Exact deadlines are the day before the lecture at 23:55

Projects:

- 1 final project with 5+ weeks for completion
- Project features in final exam
- Mid-semester: Introduction to projects
- Final exam date: deadline for projects

Thanks – Next Week: 3D Concepts