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

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How can I access these slides?

- [https://vision.in.tum.de/teaching/ws2022/seminar_realtime3d](https://vision.in.tum.de/teaching/ws2022/seminar_realtime3d)
- Material page will go online after this pre-meeting
Outline

○ General Information
  ○ About the Seminar
  ○ Registration

○ Possible Papers
  ○ Bundle Adjustment
  ○ Monocular Cameras

○ Questions
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How is the seminar organized?

- Seminar meetings: Talks and discussion
  - Day: Tuesday, approximately every second week (TBA)
  - Time: 14:00–16:00 (seminar) & 16:00–18:00 (supervisor meetings)
  - Location: hybrid (room TBA)
  - In case of special circumstances please let us know and we will find a solution
  - Each session will consist of two talks which are held in English
  - **Attendance is mandatory!**

- Talk preparation / contact with supervisor
  - One month before talk: meet supervisor for questions (optional, but recommended)
  - Two weeks before talk: meet supervisor to go through slides (optional, but recommended)
  - One week before talk: send slides to your supervisor (mandatory)
  - Two weeks after talk: submit your report via email (mandatory)
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 → 10–20 slides
  – Do not put too much information on the slides!

• Recommended structure (talk):
  – 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
  – 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 [https://matching.in.tum.de](https://matching.in.tum.de)
  - Register for: *The Evolution of Motion Estimation and Real-time 3D Reconstruction*

• **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: “[Realtime3D] application [your name]”
  - List how you fulfill the lecture requirements: See next slide
  - Attach your transcript(s)
  - Registrations without email / emails with missing information will be ignored!

• **Deadline** for both registrations: around July 21, 2022
Required Lectures for the Seminar

- To understand the content of the seminar well, we recommend students to have completed
  - A lecture on optimization, similar to Nonlinear Optimization: Advanced (MA3503)
  - A lecture on computer vision that includes geometry, similar to Computer Vision II: Multiple View Geometry (IN2228)
- You can name **up to three** lecture from your transcript that, in combination, fulfill the requirements for subdomain. Example:
  - CV & Geometry: Computer Vision I (computer vision), Projektive Geometrie 1 (for geometry)
- Please list the lectures and brief explanations in your e-mail and attach your transcript(s) as proof. **We will not scan your transcript(s) for suitable lectures!**
- If you don’t perfectly fulfill the lecture requirements you might still be able to join – this will depend on the other applicants! Thus: **Consider applying anyways if you really want to take the seminar!**
How do you register for the seminar?

Example registration email:

```
To: realtime3d-ws21@vision.in.tum.de

Subject: [Realtime3D] application [Lukas Koestler]
From: Köstler, Lukas - lukas.koestler@tum.de

Hi,
I would like to present the following papers:
1. ORB-SLAM
2. DSO
3. DTAM

I have taken the following related courses:
1. Optimization: Nonlinear Optimization: Advanced (MA2593)
2. Computer Vision & Geometry: Multiple View Geometry, Differential Geometry, Projektive Geometrie

Please find the attached transcript.

Best,
Lukas

transcript.pdf
365 KB
```
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 all criteria, selection will be random. Other students will be ranked according to the requirement fulfillment.
  - You will get notified by the matching system about the decision

- **Paper assignment**
  - Papers are assigned after the participant list is finalized
  - We give our best to accommodate your preference list in the assignment
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Bundle Adjustment in the Large
Agarwal, Snavely, Seitz, Szeliski 2010

- Proposes to solve bundle adjustment problems with an inexact Newton method linked to a preconditioner rather than by a direct factorization
- Crucial for large-scale 3D scene reconstruction

(a) Structured - 6375 photos (b) Unstructured - 4585 photos
Multicore Bundle Adjustment

Wu, Agarwal, Curless, Seitz 2011

- Presents multicore solutions to large-scale 3D scene reconstruction problems
- Based on a restructuration of the conjugate gradients solver into easily parallelizable operations
Stochastic Bundle Adjustment for Efficient and Scalable 3D Reconstruction

Zhou et al. 2020

- Integrates a clustering scheme into solving bundle adjustment
- Drastically reduces the per-iteration cost and allows distributed computing by decomposing the reduced camera matrix into subproblems
Square Root Bundle Adjustment for Large-Scale Reconstruction

Demmel, Sommer, Cremers, Usenko 2021

- Challenges the traditional Schur Complement trick
- Combines a very general theoretical derivation of nullspace marginalization with the specific structure of bundle adjustment problems
Pixel-Perfect Structure-from-Motion with Featuremetric Refinement

Lindenberger, Sarlin, Larsson, Pollefeys 2021

- Refinements of keypoint and bundle adjustments by using a featuremetric error based on dense features predicted by a neural network
- Significantly improves the accuracy of camera poses and scene geometry
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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
CNN-SLAM

Tateno et al. 2017

- Dense monocular SLAM
- Use depth map predicted from CNN
Depth from Motion for Smartphone AR
Valentin et al. 2018

- Uses poses predicted by Visual-Inertial Odometry in a Multi-View-Stereo pipeline to predict depth
- More engineering focused work that shows impressive results on CPU
• Learning a compact, optimisable representation of the scene geometry
DeepTAM: Deep Tracking and Mapping
Zhou, Ummenhofer, Brox 2018

- Learn a network to predict the pose and generate depth images
BA-Net: Dense Bundle Adjustment Networks

Tang, Tan 2019

- Use feature-metric Bundle Adjustment within a differentiable deep-learning pipeline
- Allows the end-to-end training of NNs for SLAM

von Stumberg, Wenzel, Khan, Cremers 2020

- Use feature-metric Bundle Adjustment for multi-weather relocalization
- Propose the Gauss-Newton loss to train NNs which generate feature maps that are suitable for direct image alignment
D3VO: Deep Depth, Deep Pose and Deep Uncertainty for Monocular Visual Odometry

Yang, von Stumberg, Wang, Cremers 2020

- Monocular visual odometry framework that uses deep-learning on three levels: deep depth, pose and uncertainty estimation
- Shows impressive performance improvements in comparison to traditional methods (DSO, ORB)
DROID-SLAM: Deep Visual SLAM for Monocular, Stereo, and RGB-D Cameras

Teed and Deng 2021

Figure 1: DROID-SLAM can operate on monocular, stereo, and RGB-D video. It builds a dense 3D map of the environment while simultaneously localizing the camera within the map.

- Monocular, Stereo, and RGB-D visual SLAM based on optical flow estimation (RAFT by Teed and Deng, 2020 ECCV best paper) and bundle adjustment
- Shows impressive robustness and accuracy across a wide range of datasets while trained only on the TartanAir dataset
TANDEM: Tracking and Dense Mapping in Real-time using Deep Multi-view Stereo

Koestler, Yang, Zeller, Cremers 2021

- Combines photometric tracking and deep multi-view stereo depth estimation into a monocular dense SLAM algorithm. Using depth maps rendered from the incrementally-built TSDF model improves tracking robustness.
Questions?

Reminder:

- **Web page:** https://vision.in.tum.de/teaching/ws2022/seminar_realtime3d
- **Contact:** realtime3d-ws22@vision.in.tum.de