📚 Complete Summary: Computer Vision by Prof. Andreas Geiger (Lectures 1.1 – 12.4)

🎓 Lecture 1: Introduction to Computer Vision

1.1 Course Organization - Course goals, delivery structure, prerequisites (linear algebra, probability, programming). - Mix of classical and modern computer vision.

1.2 What is Computer Vision? - Definition: Extracting information from images/videos. - The inverse problem of computer graphics. - Applications: AR/VR, robotics, autonomous driving, medical imaging, etc.

1.3 Historical Evolution - 1960s–80s: Shape-from-shading, photogrammetry, optical flow. - 1990s–2000s: SIFT, structure-from-motion, large-scale 3D recon. - 2012–present: Deep learning revolution—CNNs, Mask R-CNN, NeRF, ViTs.

📷 Lecture 2: Image Formation

2.1 Primitives and Transformations - Pinhole camera model. - Image formation equations using focal length and camera position. - Homogeneous coordinates and transformation matrices.

2.2 Geometric Image Formation - Intrinsic & extrinsic parameters. - Lens distortions. - Camera matrix: K[R|t].

2.3 Photometric Image Formation - Radiometry, albedo, BRDF. - Lambertian vs. specular reflection. - Lighting models for 3D understanding.

2.4 Sensors and Pipelines - Camera types: CCD, CMOS. - Bayer filters and RAW image processing.

🔍 Lecture 3: Structure-from-Motion (SfM)

3.1 Preliminaries - Multiple view geometry. - Camera calibration and projection.

3.2 Two-Frame SfM - Essential matrix, epipolar geometry. - Recovering camera motion.

3.3 Factorization - Tomasi-Kanade method. - Low-rank approximation of 3D points.

3.4 Bundle Adjustment - Joint optimization over all poses and points. - Minimizing reprojection error.

🎯 Lecture 4: Stereo Reconstruction

4.1 Basics - Disparity and depth. - Stereo baseline and focal length.

4.2 Block Matching - Local window-based matching.

4.3 Siamese Networks - Deep stereo matching using twin networks.

4.4 Spatial Regularization - Enforcing smoothness with MRFs/CRFs.

4.5 End-to-End Learning - Neural architectures for disparity estimation.

🧠 Lecture 5: Probabilistic Graphical Models

5.1 Structured Prediction - Modeling interdependencies in outputs.

5.2 MRFs - Grid-based models for pixels.

5.3 Factor Graphs - Message passing and inference.

5.4 Belief Propagation - Inference through iteration.

5.5 Examples - Use in stereo and segmentation.

🛠️ Lecture 6: Applications of PGMs

6.1 MRF for Stereo - Global optimization of disparity.

6.2 Multi-View Reconstruction - Combining views for coherent 3D.

6.3 Optical Flow - Temporal pixel correspondences.

🤖 Lecture 7: Learning in PGMs

7.1 CRFs - Discriminative PGMs.

7.2 Parameter Learning - Maximum likelihood, gradients.

7.3 Deep Structured Models - Combining CNNs and CRFs.

🧩 Lecture 8: Shape-from-X

8.1 Shading - Recovering shape from brightness.

8.2 Photometric Stereo - Multiple lights for surface normals.

8.3 Shape-from-X - Combining cues (motion, shading, etc).

8.4 Volumetric Fusion - Integrating depth maps into 3D volumes.

🧮 Lecture 9: Implicit Representations

9.1 Coordinate Networks - MLPs as shape functions.

9.2 Volumetric Rendering - Density fields and differentiable rendering.

9.3 NeRF - Neural radiance fields.

9.4 Generative Radiance Fields - Image generation from learned 3D scenes.

🧠 Lecture 10: Recognition

10.1 Classification - CNNs, architectures, transfer learning.

10.2 Semantic Segmentation - Pixel-wise classification.

10.3 Detection and Segmentation - RPNs, Mask R-CNN.

🌀 Lecture 11: Self-Supervised Learning

11.1 Preliminaries - Learning from unlabeled data.

11.2 Tasks - Rotation, jigsaw, colorization.

11.3 Pretext Objectives - Feature learning through proxy goals.

11.4 Contrastive Learning - SimCLR, MoCo: instance discrimination.

⚠️ Lecture 12: Advanced Topics & Ethics

12.1 Input Optimization - Adversarial examples, saliency.

12.2 Compositional Models - Capsule networks, part models.

12.3 Human Body Models - SMPL, pose regression.

12.4 Deepfakes - GANs for face reenactment, detection methods, ethical implications.