Lecture	Topics	Reading
1	2D and 3D transformations (Euclidean, similarity, affine and projective). Coordinate transformations. Homogeneous representation of points. Polar/normal and homogeneous representation of 2D lines.	**MA:** 2.1 - 2.5 (minus 2.3.2 and 2.4.2). **SZ:** 2.1.1 - 2.1.4.
2	Image representation. Lenses. Pinhole model and perspective projection. Lens and shutter distortion. Radial-tangential distortion. Extrinsics and intrinsics. Camera calibration. Calibration rigs and patterns. Image undistortion.	**MA:** 3.1 - 3.3.3. **SZ:** 6.3.1, 6.3.5. Camera calibration with Matlab.
3	Keypoint features. Point correspondence problem. Feature tracking. Image similarity functions (SSD, etc.). Image gradient. Aperture problem. Harris and Shi-Tomasi corner detector. Invariance. Scale-space. SIFT detector and descriptor. Nearest neighbor search. Lowe's ratio test (NNDR). k-d tree.	**SZ:** 4.1.1 - 4.1.4.
4	Direct linear transformation (DLT). Linear estimation algorithms. Homogeneous and non-homogeneous systems. Estimating 2D homography. SVD. RANSAC. QR decomposition. Perspective-n-Point (PnP). Estimating projection matrix with P6P.	**SZ:** 6.2.1. **HZ:** 4.1, 7.1.
5	Iterative estimation algorithms. Non-linear least squares. Residuals. Jacobian matrix. Gauss-Newton. Levenberg-Marquardt. Reprojection error.	**NW:** 2, 10 (p. 245-256)
6	Intensity transformations. Thresholding. Image histogram. Convolution. Linear and non-linear filtering. Edge detection. Hough transform.	**SZ:** 3.1, 3.2, 4.2.1, 4.3.2.
7	Two-view geometry. Triangulation. Baseline, disparity and depth. Epipolar constraint. Fundamental and essential matrix. 8-point algorithm. Reconstruction ambiguity. Degeneracies. Stereo rectification.	**HZ:** 9.1, 9.2, 9.6, 10.2, 11.1 - 11.3, 11.9, 11.12, 12.1, 12.2.
8a	Hyperspectral imaging guest lecture	Lecture is not relevant for exam
8b	Fourier and curvature scale-space descriptor for image contours.	Slides only.
9	Three- and many-view structure from motion. Hierarchical vs. incremental SfM. Bundle adjustment. Sparse bundle adjustment. Passive vs. active stereo. Photo-consistency. Active and volumetric 3D reconstruction systems.	**HZ:** 15.1, A6.3, A6.6
10	Variational methods. Variational image smoothing. Data and regularization term. Lagrangian. Descent methods. Optical flow. Real motion field. Local and global methods. Coarse-to-fine strategies.	Slides only.
11	Visual odometry systems. 2D-2D, 2D-3D and 3D-3D motion estimation. Keyframes. Windowed bundle adjustment. Drift and loop closure. Feature-based (indirect) and direct methods. Trajectory accuracy evaluation.	Tutorial on Visual Odometry by D. Scaramuzza: Part 1-2.
12	Simultaneous localization and mapping. Direct vs. indirect, sparse vs. dense. Topological and metric maps. MAP estimation. Bag-of-words place recognition. Structure of popular SLAM systems.	Slides only.
13	Recognition. Viola-Jones detector. (Un)supervised learning. k-means. Mean-shift. Support vector machines. Deep learning basics. YOLO vs. MASK-RCNN, one-stage vs. multi-stage.	**SZ:** 14.1, 14.2, 14.4.1 SVM classifier by A. Zisserman.

Final curriculum (pensum) includes lecture slides, all exercises (including the theory introductions), and the reading list above. The chapters are selected from the following textbooks, which can be downloaded from Piazza.

MA: Ma, Soatto, Kosecka, Sastry. An Invitation to 3D Vision. 2004.

SZ: Szeliski. Computer Vision: Algorithms and Applications. 2011.

HZ: Hartley and Zissermann. Multiple View Geometry in Computer Vision 2nd Ed..

NW: Nocedal and Wright. Numerical Optimization. (Free on SpringerLink)

We also refer to these resources:

Camera calibration with Matlab

Tutorial on Visual Odometry by D. Scaramuzza

SVM classifier by A. Zisserman

We previously referred to the textbooks of Corke and Forsyth&Ponce, as these can be easier-to-read alternatives for a subset of the topics. These are available on Piazza but are not required reading. Gonzalez was referred to in L6, but for the final curriculum we have substituted this with relevant chapters in Szeliski.