CVonline wiki

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Geometry and mathematics

A part of the CVonline computer vision resource summarizing the geometric and mathematical methods commonly encountered in computer vision and image processing.

1. Basic Representations
    1. Coordinate systems
        1. Cartesian coordinate system
        2. Cylindrical coordinate system
        3. Hexagonal coordinate system (see external links)
        4. Log-Polar coordinate system
        5. Polar coordinate system
        6. Spherical coordinate system
    2. Digital topology
    3. Dual space
    4. Homogeneous coordinates
    5. Pose/Rotation/Orientation Representations
        1. Axis-angle representation
        2. Clifford algebra
        3. Euler angles
        4. Exponential map
        5. Quaternion/Dual quaternion
        6. Rotation matrix
        7. Pitch/Yaw/Roll
2. Distance and similarity metrics
    1. Affine distance
    2. Algebraic distance
    3. Bregman divergence
    4. Bhattacharyya distance
    5. Chi-square test/metric
    6. Curse of dimensionality
    7. Earth mover's distance
    8. Euclidean distance
    9. Fuzzy intersection
    10. Hausdorff distance
    11. Jaccard Index
    12. Jeffrey divergence
    13. Jensen-Shannon Divergence
    14. Kullback–Leibler divergence

System models, calibration and parameter estimation methods
Visual learning related methods and concepts
Sitemap

15. Mahalanobis distance
16. Manhattan/City block distance
17. Minkowski distance
18. Procrustes analysis
19. Quadratic form
20. Sørensen-Dice coefficient
21. Specific structural similarity
    1. Curve similarity
    2. Region similarity
    3. Volume similarity

3. Elementary mathematics for Vision
    1. Coordinate systems/Vectors/Matrices/Derivatives/Gradients/Probability
    2. Derivatives in sampled images
4. Mathematical optimization
    1. Golden section search
    2. Lagrange multipliers/Constraint optimization
    3. Multi-dimensional optimization
        1. Random optimization
        2. Global optimization
            1. Ant colony optimization
            2. Downhill simplex
            3. Genetic algorithms
            4. Graduated optimization
            5. Markov random field optimization
            6. Particle swarm optimization
            7. Simulated annealing
        3. Optimization with derivatives
            1. Levenberg–Marquardt
            2. Gradient descent
            3. Quasi-Newton method
    4. Model selection
    5. Variational methods
5. Linear algebra for computer vision
    1. Eigenfunction
    2. Eigenvalues and eigenvectors
    3. Norms
        1. Frobenius
        2. Hamming
        3. L or p norms (1, 2, ∞)
        4. Manhatten or taxi
        5. Nuclear
        6. Spectral
    4. Principal component and Related Approaches
        1. Dimensionality reduction
        2. Linear discriminant analysis
        3. Factor analysis
        4. Fisher's linear discriminant
        5. Independent component analysis

6. Kernel linear discriminant analysis
7. Kernel principal component analysis
8. Locality preserving projections
9. Non-negative matrix factorization
10. Optimal dimension estimation
11. Sufficient dimension reduction
12. Principal component analysis/Karhunen–Loève theorem
13. Principal geodesic analysis
14. Probabilistic principal component analysis
15. Rao–Blackwell theorem

5. Sammon projection
6. Singular value decomposition
7. Structure tensor

6. Multi-sensor/Multi-view geometries
    1. 3D reconstruction
        1. 3D shape from 2D projections
        2. 3D reconstruction from multiple images
        3. Slice-based reconstruction
    2. Projective reconstruction
    3. Baseline stereo
        1. Narrow baseline stereo
        2. Wide baseline stereo
    4. Binocular stereo algorithms
        1. Cooperative stereo algorithms
        2. Binocular disparity
            1. Subpixel disparity
        3. Dense stereo matching approaches
        4. Dynamic programming (stereo)
        5. Feature matching stereo algorithms
        6. Gradient matching stereo algorithms
        7. Image rectification
            1. Planar rectification
            2. Polar rectification
        8. Log-polar stereo
        9. Multiresolution analysis
        10. Panoramic image stereo algorithms
        11. Phase matching stereo algorithms
        12. Region matching stereo algorithms
        13. Weakly/Uncalibrated stereo approaches
        14. Spherical stereo
    5. Epipolar geometry/Multi-view geometry
        1. Absolute conic
        2. Absolute quadric
        3. Essential matrix
        4. Fundamental matrix
        5. Grassmannian space/Plücker embedding
        6. Homography tensor
        7. Transfer and novel view synthesis

8. Trifocal tensor
6. Image-based modeling and rendering
7. Plenoptic modeling
8. Image feature correspondence
    1. Active stereo
    2. Disparity gradient limit (feature correspondence)
    3. Epipolar constraint
    4. Feature contrast
    5. Feature orientation
    6. Grey-level similarity (feature correspondence)
    7. Lipschitz continuity
    8. Surface continuity
    9. Surface smoothness
    10. View consistency constraint
9. Scene reconstruction/Surface interpolation
    1. Adaptive mesh refinement
    2. Constrained reconstruction
    3. Thin plate models
    4. Texture synthesis/Texture mapping
    5. Triangulation
    6. Volumetric reconstruction
        1. Visual hull
10. Trinocular (and more) stereo

7. Parameter Estimation
    1. Bayesian methods
    2. Constrained least squares
    3. Linear least squares
    4. Optimization
    5. Robust techniques
8. Probability and Statistics for Computer Vision
    1. Autoregression
    2. Bayes estimator
    3. Bayesian inference networks
    4. Canonical correlation
    5. Causal models
    6. Correlation and dependence
    7. Covariance and Mahalanobis distance in Vision
    8. Dempster–Shafer theory
    9. Density estimation
    10. Gaussian or Normal distribution
    11. Heteroscedastic noise
    12. Hidden Markov models
    13. Homoscedastic noise
    14. Information theory
    15. Kalman filters
        1. Unscented Kalman filters
    16. Kernel regression

17. Least mean squares estimation
18. Least median square estimation and estimators
19. Log-normal distribution
20. Logistic regression
21. Markov chain/Markov chain Monte Carlo methods
22. Markov random field
    1. Applications
    2. Conditional random fields
    3. Multi-level Markov random fields
    4. Optimization methods
        1. Gibbs sampling
        2. Graduated optimization
        3. Graph cuts in computer vision
        4. Iterated conditional modes
        5. Simulated annealing
23. Maximum likelihood
24. Mixture models and expectation-maximization (EM)
    1. Gaussian mixture model
    2. Categorical mixture model
25. Model/Curve fitting
26. Monte Carlo method
27. Multimodal distribution
28. Normalization
29. Non-parametric statistics
    1. Non-parametric regression
    2. Kernel density estimation
30. Point process
31. Poisson distribution
32. Probability axioms
33. Random number generation
34. Robust estimators
35. Statistical hypothesis testing/Analysis of variance
36. von-Mises-Fisher and other directional statistics

9. Projective geometry/Projective transformations
    1. Affine projection model/Affine transformation
    2. Anamorphic projection/Catadioptric system
    3. Central cylindrical projection
    4. Orthographic projection
    5. Map projection
    6. Homography
    7. Hierarchy of geometries
    8. Perspective projection
    9. Projective plane
    10. Projective space
    11. Real camera projection
    12. Similarity matrix
    13. Weak-perspective

        1. Tomasi-Kanade factorization
10. Projective invariants/cross-ratio
    1. Absolute points (points at infinity)
    2. Affine invariants
        1. Affine geometry of curves
    3. Collineation
    4. Conics/Quadrics
    5. Coplanarity
    6. Differential invariants
    7. Duality
    8. Integral invariants
    9. Laguerre formula
    10. Pencils
    11. Quasi-invariants
    12. Structural invariants
        1. Cartan's equivalence method
11. Relational shape descriptions
    1. Curves
        1. Adjacency/Connectedness
        2. Relative curvature
        3. Relative length
        4. Relative orientation
        5. Separation
    2. Regions
        1. Adjacency/Connectedness
        2. Relative area/size
        3. Separation
    3. Surfaces
        1. Adjacency/Connectedness
        2. Relative area/size
        3. Relative orientation
        4. Separation
    4. Volumes
        1. Adjacency/Connectedness
        2. Relative orientation
        3. Relative volume/size
        4. Separation
12. Shape properties
    1. Geometric Morphometrics
    2. Kendall´s Shape Space
    3. Points and local invariants
        1. Scale-invariant feature transform
    4. Curves and Curve Invariants
        1. Affine curvature
        2. Arc length
        3. Bending energy
        4. Chord distribution
        5. Curvature, Torsion of a curve, Radius of curvature

6. Differential geometry, Frenet–Serret formulas
7. Invariant Points: Inflections/Bitangents

5. Image regions and region invariants
    1. Compactness measure of a shape
    2. Area
    3. Perimeter
    4. Center of mass, Centroid
    5. Eccentricity, Elongatedness
    6. Euler number/Genus
    7. Extremal points
    8. Feret's diameter
    9. Fourier descriptors
    10. Minimum bounding rectangle
    11. Image moments
        1. Affine moments
        2. Bessel-Fourier moments
        3. Binary moments
        4. Color moments
        5. Central moments
        6. Eigenmoments
        7. Fourier-Mellin moment invariants
        8. Gaussian-Hermite moments
        9. Texture moments
        10. Hahn moments
        11. Krawtchouk moments
        12. Legendre moments
        13. Orthogonal moments
        14. Racah moments
        15. Chebyshev moments
        16. Zernike and velocity moments
    12. Orientation
    13. Sphericity
    14. Rectangularity
    15. Rectilinearity
    16. Roundness
    17. Topological invariants
        1. Euler characteristic
6. Differential geometry of surfaces
    1. Parametric surfaces
    2. Common shape classes and representations
        1. Cone representations
        2. Cyclide
        3. Cylinder representations
        4. Ellipsoid/Sphere Representations
        5. Thin plate splines
        6. Plane representations
        7. Polyhedra representations

8. Quadric representations
9. Torus representations

3. Fundamental surface forms
    1. First fundamental form
    2. Second fundamental form
4. Gauge coordinates
5. Hessian
6. Laplace–Beltrami operator
7. Metric derivative
8. Principal curvature and directions and other local shape representations
    1. Deviation from flatness
    2. Gauss–Bonnet surface description
    3. Gaussian curvature
    4. Koenderink's shape classification
    5. Mean curvature
    6. Minimal surface
    7. Parabolic points
    8. Ridges
    9. Umbilics
9. Quadratic variation
10. Ricci flow
11. Surface area
12. Surface normals and tangent planes
13. Orientability

7. Symmetry
    1. Affine symmetry
    2. Bilateral symmetry
    3. Rotational symmetry
    4. Skew symmetry
8. Volumes
    1. Elongatedness
    2. 3D moments and moment invariants
9. Volume

13. Transformations (geometric), registration and pose estimation methods
    1. Pose estimation
    2. 2D to 2D pose estimation
        1. Methods
    3. 2D to 3D pose estimation
        1. Methods
    4. 3D to 3D pose estimation
        1. Methods
    5. Affine transformation
        1. Minimal data estimation
    6. Bundle adjustment
    7. Euclidean transformation
        1. Least-square euclidean transformation estimates

    2. Minimal data euclidean transformation estimation
    3. Robust euclidean transformation estimates
8. Homographic transformation
    1. Least-square homography transformation estimates
    2. Robust homography transformation estimates
9. Kalman filter pose estimation methods
10. Partially constrained pose
    1. Incomplete information
    2. Intrinsic degrees of freedom
11. Projective transformation
    1. Direct linear transformation
    2. Robust estimates
12. Similarity transformation
13. Articulated body pose estimation

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