Revision and the Exam

COSC 470: Special Topic
Computer Vision | 3D Reconstruction
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Overview

- Creating 3D models from 2D images
  - Feature detection and pair-wise matching
  - Estimate Fundamental/Essential matrices
  - Decompose *E* to give rotation and translation
  - Recover 3D point locations
  - Pose estimation for future cameras
  - Bundle adjustment
  - Surface fitting

Images and Filtering

- Representing images, colour spaces, etc.
- Filtering images
  - Mean filter, Sobel filters, Gaussian filters
  - Filters at the edges of images
  - Separable filters

Feature Detection

- Features – repeatable, well localised
- Harris and Stephens corner detector
  - High image gradient in all directions
- Difference of Gaussians blob detector
  - Use of pyramid structure for different scales

Feature Description and Matching

- Basic descriptor – a patch from the image
- More robust approaches – eg: histogram of gradient magnitudes
- SIFT descriptors
  - Orientation and scale invariance
- Feature matching – kd-Trees

Cameras and Transforms

- Maths – vectors, matrices, transforms
- Homogeneous co-ordinates
- Types of transforms – homographies
- Pinhole camera model – $x = K[R|t]X$
- Camera calibration matrix, K

Estimating Transforms

- Direct Linear Transform for homographies
- SVD for homogeneous equations
- Normalisation of co-ordinate frames
- RANSAC to remove outliers

Image Mosaicing

- A 2D analogue to the 3D problem
- Pairwise mosaicing by estimating homography
- Seam detection
- Mosaicing multiple images
- Problems with misalignment

Stereo Geometry

- Epipolar geometry
- The Fundamental and Essential matrices
- 8-point algorithm for Fundamental matrix
- Similar issues to Homography estimation
- 5-point algorithm for Essential matrix

3D Motion and Structure

- Recovering rotation and translation from *E*
- Four solutions, only one makes sense
- Computing 3D structure from two views
- Rays don't quite intersect – reprojection error
- Perspective n Point (PnP) pose estimation

Bundle Adjustment

- Non-linear least squares optimisation
- Measurements – 2D image feature locations
- Parameters – Cameras and 3D point locations
- Gradient descent vs Gauss-Newton methods
- Levenberg-Marquardt algorithm
- Jacobian matrix, sparsity, and differentiation

RGB-D Sensing

- A bit of an aside from the main story
- Sensors like the Kinect measure depth directly
- Basic approach is structured light
- Geometry much the same as with stereo
- Combining point clouds, ICP algorithm

Surface Reconstruction

- Approximating vs Interpolating methods
- Delaunay triangulation in 2D
- Poisson reconstruction
- Surface texturing

The Exam

- Worth 40% of your final mark
- 4 Questions, 20 marks each
  - Filters and Features
  - Cameras and Transforms
  - Stereo Geometry
  - Estimation and Optimisation

Filters and Features

- Mostly lectures 2, 3, and 4
- Image filtering
- Feature detection
- Feature description
- Feature matching

Cameras and Transforms

- Mostly lectures 5, 6, and 7
- Homogeneous co-ordinates and transforms
- Homographies for image mosaicing
- Estimating transforms
- Camera model – $x = K[R|t]X$

Stereo Geometry

- Mostly lectures 8 and 9
- Epipolar geometry
- Fundamental and Essential matrices
- 8-point and 5-point algorithms
- Stereo reconstruction

Estimation and Optimisation

- Mostly lectures 6, 10, and 12
- Random Sample and Consensus RANSAC
- Non-linear least squares estimation
- Levenberg-Marquardt
- Surface estimation