In-Loop Radial Distortion Compensation for Long-Term Mosaicing of Aerial Videos

Holger Meuel · Stephan Ferenz · Marco Munderloh · Hanno Ackermann · Jörn Ostermann

Scenario and Goal

Goal: Fully automatic panorama image generation from aerial videos

- Scenario: Planar, vertical aerial video from UAV affected by (radial) lens distortions
- Feature point-based homography estimation from video frames
- Automatic lens distortion correction challenging in typical approaches
- Lens distortion correction implicitly modeled
- Extension for large automatically generated panorama images

Joint Homographies and Radial Distortion Estimation

- Model radial distortion as Taylor series, consider only 1st order:
  \[ x_0 = x_0(1 + r^2 x_1) = x_0 + x_0^2 x_1 + \ldots \]
  \[ y_0 = y_0(1 + r^2 y_1) = y_0 + y_0^2 y_1 + \ldots \]
- Projective transform (homography) of a point \( x_0 \) from one frame to a second frame in homogeneous coordinates:
  \[ x_0' = H \cdot x_0 \]
- Concatenation of several homographies:
  \[ x_0'' = (H_n \cdots H_1) \cdot x_0' \]
- Joint estimation of homographies and unknown constant \( \kappa_1 \):
  \[ H_{n-k} \cdots H_n \]

Joint estimation of \( H_{n-k} \cdots H_n \) and unknown constant \( \kappa_1 \): In-Loop Radial Distortion Compensation

- Decompose \( H \) into rotation \( R \), translation \( t \), camera matrices \( K, K' \), surface normal \( \hat{n} \), distance between camera \( d \):
  \[ H = K'(R - \hat{n} d)K^{-1} \]
- Iteratively optimize radial distortion parameter \( \kappa_1 \) in a gradient descent (over an entire picture group (PG)) to physically possible rotation changes so that:
  \[ |\frac{d\theta_x(t)}{dt}| < c_x, \quad |\frac{d\theta_y(t)}{dt}| < c_y \]

Fast approximative solution: In-Loop Radial Distortion Compensation

- Idea: Regularize change in size and shape of projection
  \[ x_0'' = (H_n \cdots H_1) \cdot x_0' \]

Experiment Results

Joint homographies & radial distortion estimation

- Noise-free, artificially generated point clouds, \( N \approx 1000 \) points each
- Randomly sampled \( S \approx 30 \) points for homography estimation
- Exponential run time increase
  \[ \Rightarrow \text{Impractical for real systems} \]

In-loop radial distortion compensation

- 14 iterations, 60 frames/picture group (PG)
- Limit rotations by geometrical constraints
- Max. change in size and shape: \( c_{\text{size,max}} = 20 \% \)
  and \( c_{\text{shape,max}} = 10 \% \) per PG
- 1000 ms/frame if iterating, 200 ms/frame if not (not optimized)
- 0.0044 pel/frame drift compared to Google Earth

Summary

- Joint model for estimation of several homographies and unknown constant radial distortion
- Fast approximative solution due to exponentially increased run time for higher number of jointly estimated homographies
- Regularization of projection for jointly estimated picture group based on geometrical constraints
- Fully automatic mosaicing of unpreprocessed video frames
- Panorama images generated from more than 1500 uncalibrated, not preprocessed video frames

Institut für Informationsverarbeitung
Holger Meuel
meuel@tnt.uni-hannover.de
http://www.tnt.uni-hannover.de/project/roi_2