Projective indices for AR/MR benchmarking in TrakMark

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Image based tracking for AR/MR

Tracking with artificial markers
“ARToolKit” (Kato, et al)

Tracking with interest points
“PTAM” (G. Klein, et al)

How do we benchmarking the estimated camera parameters?
Issues in the benchmarking

1: Ground truth of camera parameters is needed for accuracy evaluation.
2: Common data set and indices are needed for comparative evaluation.
3: Data set should be able to be customized for users’ own situations.
Data set with ground truth (or reference data)

The Yosemite sequence (by Lynn Quam)

TrakMark benchmark

Outdoor | Indoor | Virtualized reality

Sequences provided with ground truth (or reference) of extrinsic camera parameter

Issues in the benchmarking

- Common (customizable) data set
- Ground truth (or reference)

- Common indices?
Objective

• Common indices
  – Positional / Rotational error of camera pose
  – Re-projection error of interest points
  – (Add) Projective indices of virtual points

for AR/MR applications

• Two stage projective indices
  – Visibility indices of virtual points
  – Projection errors of virtual points
Projective indices:
Projection error of virtual objects

- Projection error is important for AR/MR applications
- We discuss appropriate parameters of “Projective indices” for easy and fair comparison

How many objects? Where to place?
Placement strategy of virtual objects

Object = point
Relative placement: points in the view

Virtual points are placed on a Virtual plane

Distance $d$

Camera position

Image plane

Virtual plane

(Ground truth camera)
Placement strategy of virtual objects

Change the distance

Distance \( d \)

Camera position

Image plane

Virtual points

• Individual error
  - Detailed examination

• Mean error
  - Single (comparable) index
Evaluation of SLAM

- Mean projection error of $3 \times 3 = 9$ points
- Distances: 1, 2, 5, 10, 50, 100 [m]
- Virtualized reality and outdoor sequences
- SLAM implementation is available online
Model creation for virtualized reality

Virtualized reality sequence

Image size: 640x480 pix
Result: geometric indices of camera pose

Position [m]

Rotation [deg]

Euclidean distance

Rotation Error

Position Error

Rotational error
Mean projection error of 3x3 points

Image size: 640x480 pix
Outdoor sequence

Image size: 720x480 pix
Result: geometric indices of camera pose

- Euclidean distance
- Rotation error [rad]
- Position error [mm]
- Rotation angle [deg]

Graphs showing variations in position and rotation over frame number.
Mean projection error of 3x3 points

Frame number

Mean projection error [pix]
Comparison of camera tracking results

- Landmark based method
- SLAM based method
Position error

Position Error (SLAM)

Calculated at 1071/1071 frame

Position Error (Landmark)

Calculated at 69/1071 frame
Rotation error

Rotation Error (SLAM)
Calculated at 1071/1071 frame

Rotation Error (Landmark)
Calculated at 69/1071 frame
Projection error of virtual objects

SLAM based method
(1071/1071 frame)

Landmark based method
(69/1071 frame)

Projection errors are not so vary from the position of the virtual point.

How can we evaluate a number of tracked frames?
Experiment with 3D model

Virtualized reality model used in the experiment.
(Shopping mall in Osaka, Japan)
1. Data set generation

Camera path creation with walking motion

Generated images with virtualized reality models
2. Creation of key frames

We manually selected four images as key frames used by the tracking method.
3. Generation of interest points
4. Camera tracking with generated images

Estimated camera path (red)

Ground truth (green)
5.1 Evaluation of camera positions
5.2 Rotation errors calculated by using difference Matrix

\[ R_d = R_g R_e^T \]

\[ \theta_{R_d} = \arccos((\text{tr}(R_d) - 1)/2) \]
5.3 Projection errors of virtual objects

A distance from the camera to the virtual plane

Virtual plane

Image plane (Ground truth)

Image plane (Estimated camera parameters)

Calculation result

A = 1000 [mm]
5.3 Projection errors of virtual objects (with various distances)

Features:
- Errors become larger over time (similar to position and rotation errors)
- Errors become smaller when the distance increases
Projection errors \((a = 1000 \text{ [mm]})\)
Projection errors \((a = 3000 \text{ [mm]})\)

Projection errors are vary from the position of the virtual point.
A number of feature points on the image plane

We count a number of feature points on the image plane (9 areas).

A number of feature points decreases.

Projection error of virtual objects becomes larger.
Conclusion

Projective indices for AR/MR benchmarking in TrakMark

– Projective indices of virtual points for AR/MR applications
– Two stage projective indices
  • Visibility index of virtual points
  • Projection errors of virtual points
– Relative placement strategy of virtual objects

~ Future works ~

– Standardization of projective indices
– Expansions of benchmarking results in TrakMark
Thank you!

- TrakMark
  http://trakmark.net/

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Provision of our data set on website
http://trakmark.net/

Data discs (distributed in ISMAR2013)