A benchmark suite with virtualized reality models for supporting tracking evaluation and data set generation

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Our background: Virtualized reality models in service research

Visualization of worker’s trajectory in “Ryokan” (Japanese traditional hotel)

Many opportunities to create virtualized reality models

PDR (Pedestrian dead reckoning) demonstration in a social event
Image Based Tracking for AR

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 able to be customized for users’ own situations.
Objective

Construction of a benchmark suite for supporting tracking evaluation and data set generation

Approach

- We apply virtualized reality models.
  - ✔ Ground truth data are available.
  - ✔ Users can generate arbitrary camera path.

We construct standards in two categories.

- Dataset-format
- Indices for benchmarking camera tracking method

We plan to standardize benchmarking methods in “ISO / JTC1 / SC24 / WG9 (Augmented reality continuum concepts and reference model)”
Related works:
Data set with ground truth (or reference data)

The Yosemite sequence (by Lynn Quam)

A Benchmark for the Evaluation of RGB-D SLAM Systems
(J. Sturm et al, IROS2012)
Proposed framework

Server

Benchmark resources

A : Datasets
(Generated images, Camera parameters, Image features)

Provision of datasets with various properties

B : Benchmark suite
(Virtualized reality models, Camera paths, Supporting tools)

- Support for dataset creation and benchmarking
- Datasets compression

C : Expansions for supporting tools
(Camera motion models, Adding of original objects, etc.)

Support for specific situations

Sharing of benchmarking results

- Position and posture errors
- Re-projection error of image features
- Computational cost (time)
- Re-projection error of image features
- The number of datasets used for benchmarking and the variety of property
Benchmarking for comparison purposes

User

Server

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Download

Benchmarking of tracking methods (with benchmark suite)

Submission of the result
User’s own benchmarking

Benchmarking of tracking methods (with benchmark suite)

Dataset creation

Registration of new datasets

Download

Benchmark resources

A : Datasets
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Sharing of benchmarking results

Position and posture errors

Re-projection error of image features

Computational cost (time)

Re-projection error of image features

The number of datasets used for benchmarking and the variety of property

User

Server

Datasets compression

Support for dataset creation and benchmarking
## Classification

<table>
<thead>
<tr>
<th>Reality</th>
<th>Cost of modeling</th>
<th>Cost of creating reference data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real world</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Virtualized reality model</td>
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<td>High</td>
</tr>
<tr>
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### Issues in our research

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Model creation in our laboratory

Proposed tool for generating data set

Setting up of control points.

Camera path creation with linear interpolation.

Generated images. (Camera parameters of the images are available.)

Data of interest points. (3D-2D correspondences are known.)
Appearance of generating data set with the tool
Videos captured by Head Mounted Camera and Hand Held Camera

Walking motion

Blur
Modelization of walking motion

Walking motion model is introduced to the tool for simulating a motion of head-mounted camera.
Results of applying walking motion models

Settings of parameters
• Basic height 1600 [mm]
• Vertical variance 50 [mm]
• Horizontal variance 80 [mm]
• Yaw variance 1 [degree]
• Walking step length 650 [mm]
• Walking speed 900 [mm]
Functions for applying defocus blur and motion blur

Normal images

Images with defocus blur
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 Evaluation of rotation error (Euler angle)

Euler angle (raw values)

Errors of Euler angle
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 error of virtual objects

Calculation procedure

Virtual plane

Image plane (Ground truth)

Position of virtual object

Virtualized reality models

Image plane (Estimated camera parameters)

Same coordinate systems are set on the planes

Calculation procedure

Virtual plane

Image plane (Ground truth)

Position of virtual object

Virtualized reality models

Image plane (Estimated camera parameters)

(u,v)

(u',v')

(u,v)

(u',v')
5.3 Projection errors of virtual objects

Virtual plane

A
B
C
D
E
F
G
H
I

Image plane

Ground truth

(u,v)

(u',v')

Image plane

Estimated camera parameters

A distance from the camera to the virtual plane

A = 1000 [mm]

Image size

640

480

Calculation result

No. of frames
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 [mm])

Projection errors are vary from the position of the virtual point.

↓

There is the potential for optimization of tracking methods with position of the virtual point.
Effects of the walking motion

Projection errors (average of nine points)

Walking motion: OFF

Walking motion: ON
Conclusion

Virtualized reality model-based benchmarking of camera tracking methods in TrakMark.

– Standardization in two categories
  • Dataset-format
  • Indexes for benchmarking camera tracking method

– Development of the benchmark suite for supporting
  • Dataset creation
  • Benchmarking process

~Future works~

– Provision of benchmarking results
– Additional expansions for the tool
  (Additional camera motion models, Introduction of motion capture data, Change of lighting, … etc)
Thank you!

- TrakMark
  [http://trakmark.net/](http://trakmark.net/)

- Center for Service Research, AIST

- Koji Makita (Post doctoral research scientist)
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