Real-time Geometric Registration of Real and Virtual Worlds Using a Feature Landmark Database with Priorities

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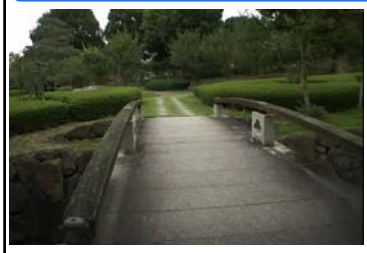
Augmented Reality



Real World

Virtual World

Camera positions and postures are required

Geometric Registration

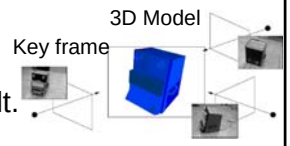
Mixed real and virtual worlds

Requirements for camera parameter estimation

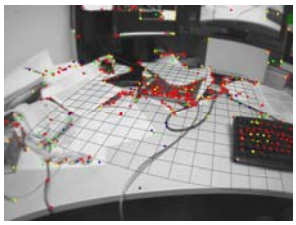
- Applicable to various environments
- Absolute position and posture can be estimated
- Work in real-time

Related Work in Geometric Registration

- Sensor based method
  - Geometric registration in pixel order is difficult.
- Model based method
  - Application for complex environments is difficult.
- Feature point based method
  - Application for complex environments is easy.



[Vacchetti et al. 2004]

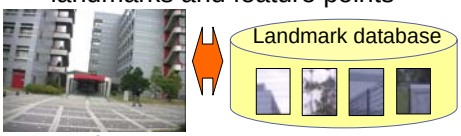


[Klein et al. 2007]

Visual SLAM based method

Can not estimate absolute camera position and posture

Correspondence between landmarks and feature points



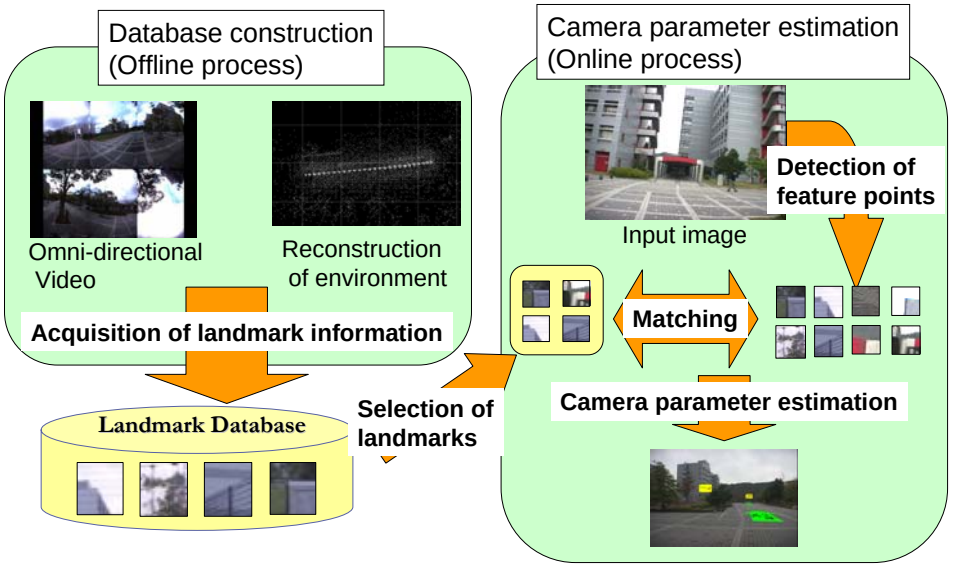
Input image

[Oe et al. 2005]

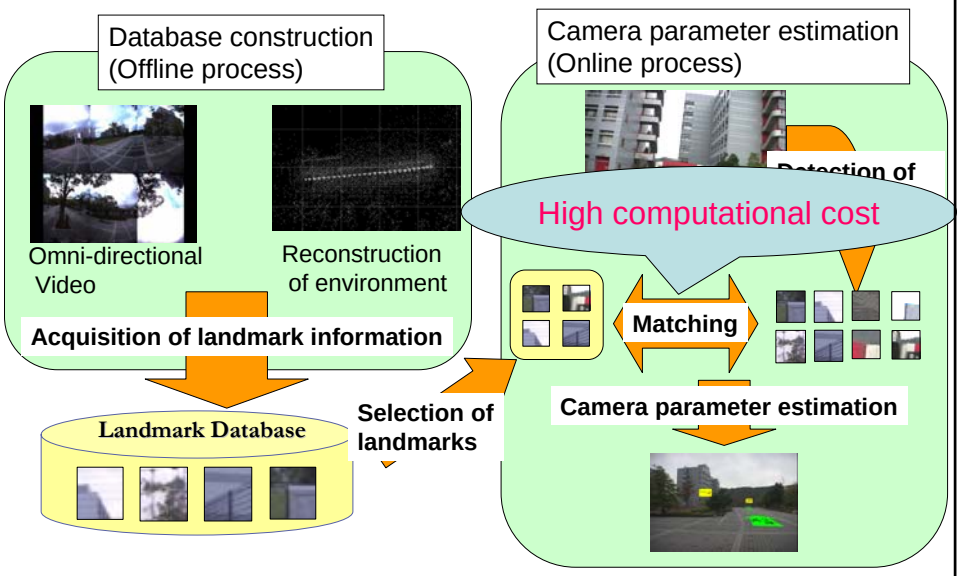
Feature landmark based method

Can not work in real-time

Flow of Our Previous Method (Oe et al. 2005)



Flow of Our Previous Method (Oe et al. 2005)



Goal and Approach

Goal

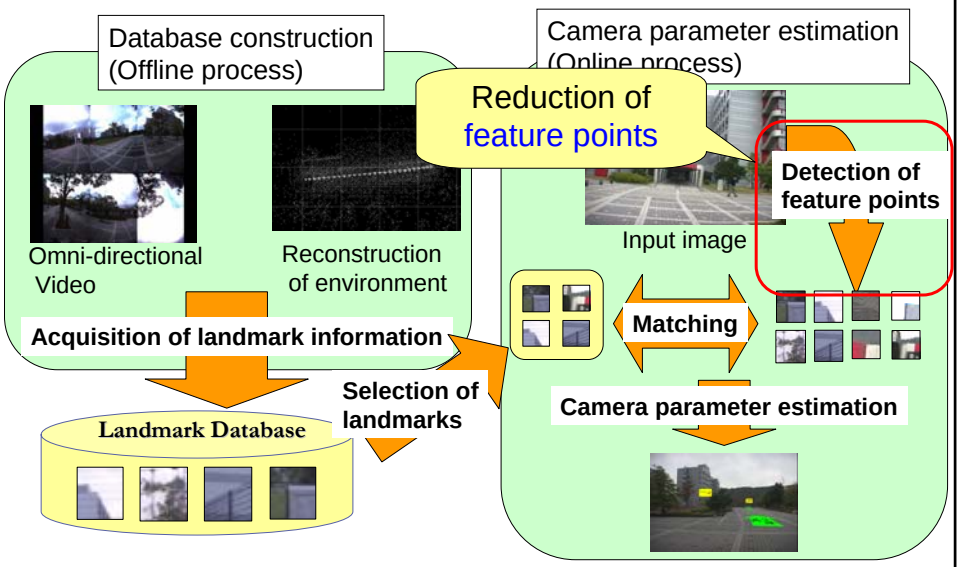
Real-time geometric registration using feature landmark database

Approach

Reduction of matching pairs :

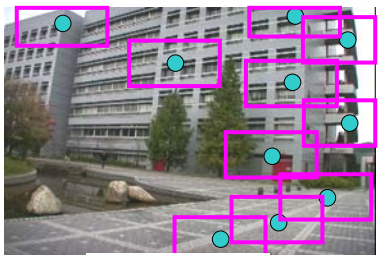
- **Reduction of feature points** by estimating tentative camera parameter
- **Reduction of landmarks** by selecting landmarks with high priorities

Registration Using Landmark Database



Feature Selection

Range of search is usually determined by camera parameters of the previous frame.



Current frame

Projected position of landmark

Range of search

Camera position and posture of the previous frame

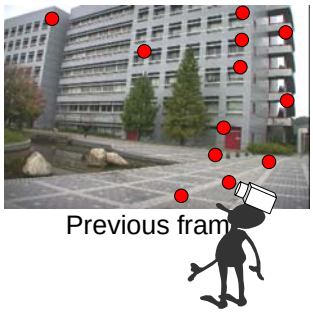
Problem

Range of search is very large.

→ A lot of feature points are tested as matching candidates.

Reduction of Feature Points

Reduction of feature points by estimating tentative camera parameters.



Previous frame

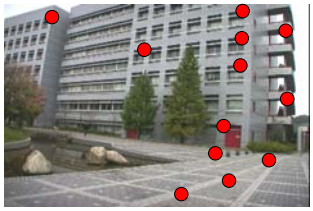
Current frame

Camera position and posture of the previous frame

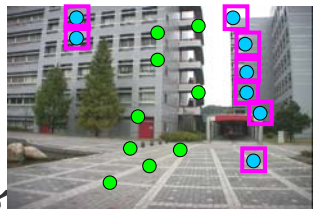
- Position of landmarks in the previous frame

Reduction of Feature Points

Reduction of feature points by estimating tentative camera parameters.



Previous frame



Current frame

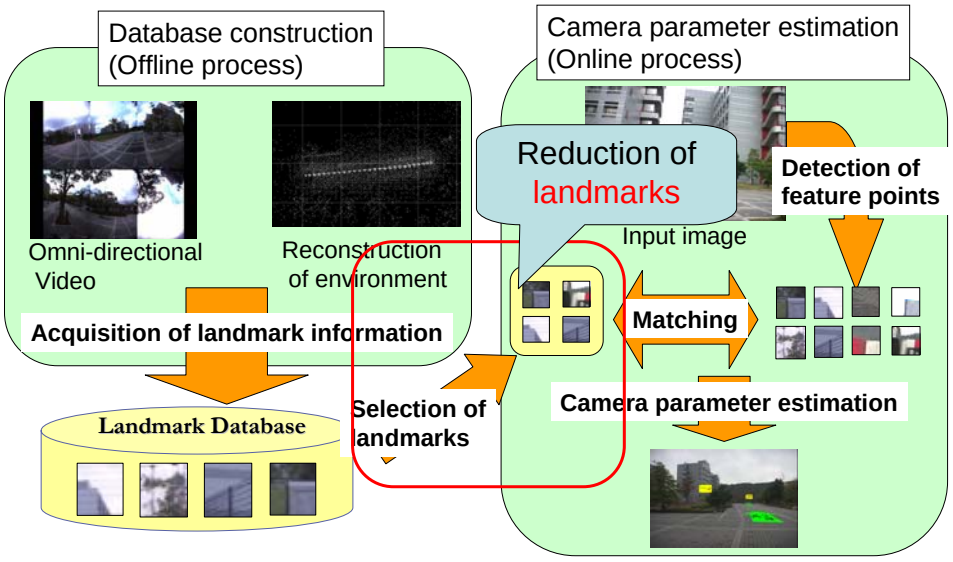
Tentative camera position and posture

- Position of landmarks in the previous frame
- Position of landmarks in the current frame
- Projected position of landmark

Range of search becomes smaller than that in the previous method.

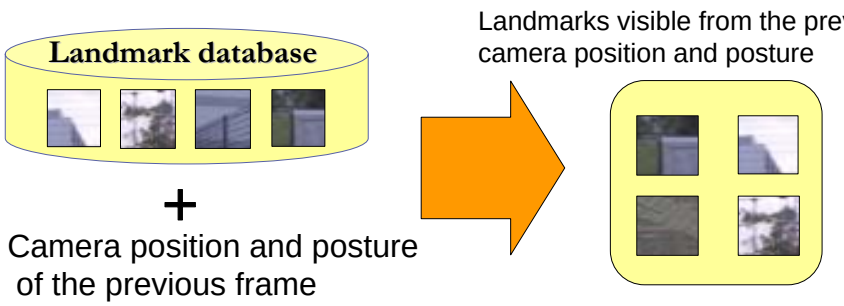
⇒ **The number of feature points is reduced**

Registration Using Landmark Database



Landmark Selection

Landmarks are selected based on geometric information.



Problem:

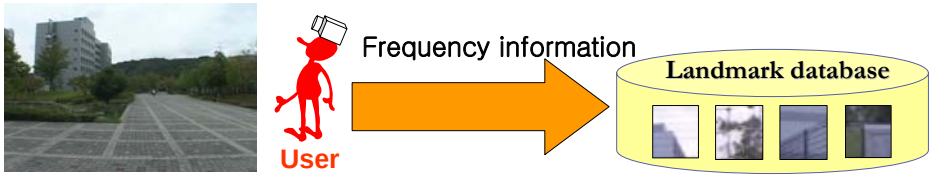
Ineffective landmarks are often selected from the database.

Calculation of Priorities of Landmarks

Priorities are determined by calculating probabilities that landmarks are used in camera parameter estimation.

$$P_i = E_i / S_i$$

E_i: Frequency that the landmark i is determined as an inlier by robust estimation.
S_i: Frequency that the landmark i is selected from the database.



Priorities are updated by estimation results

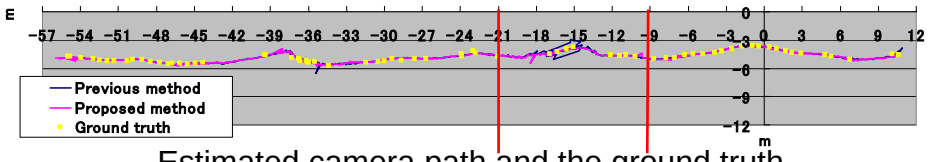
Experiments

The proposed method is compared with the previous method [Oe et al.05] with respect to the robustness and the computational cost.

Experimental conditions

	Previous method	Proposed method
Input image	Resolution 720x480 pixels, 15 fps, 1000 frames	
Camera	SONY DSR-PD-150	
PC	Core 2 Extreme 2.93GHz, Memory 2GB	
Image template size of landmarks	15×15 pixels	
Range of search in tracking process	-	120×60 pixels
Range of search in matching process	120×60 pixels	20×20 pixels
Learning data	-	Estimation results of three sequences
Initial value of priorities	-	0.5

Evaluation of the Robustness



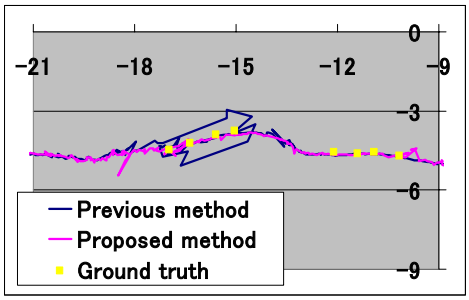
Estimated camera path and the ground truth

※ The ground truth is created by manually corresponding between landmarks and features.
※ Number of landmarks selected from database: 100 per frame

Comparison of accuracy

	Previous method	Proposed method
Error in position (mm)	220	226
Error in optical axis (degree)	0.37	0.41

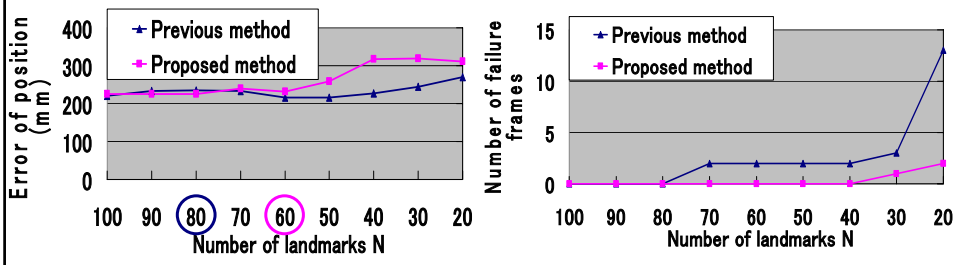
Evaluation of the Robustness



Previous method

Proposed method

Reduction of Landmarks by Using Priorities



Comparison of accuracy

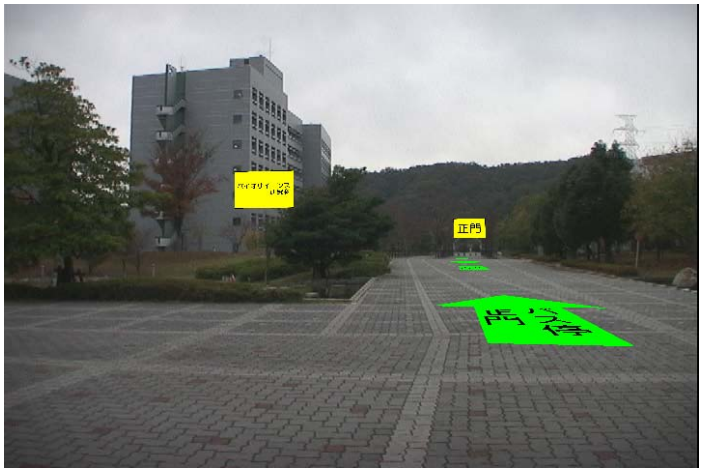
	Previous method (N=80)	**Proposed method** (N=60)
Error in position (mm)	235	231
Error in the optical axis (degree)	0.39	0.42

Improvement of Computational Cost

	processing time (ms)		**Ratio of processing time**
	Previous method (N=80)	**Proposed method** (N=60)	
Estimation of tentative camera parameter	-	28	-
Landmark selection	12	1	0.08
Matching	316	15	0.05
Camera parameter estimation	61	17	0.28
Other processing	4	5	1.25
total	393(2.5fps)	66(15.1fps)	0.16

The proposed method can work in real-time.

Result of Registration



Number of landmarks selected from database: 60
Processing time：66 milliseconds per frame

Summary

- We propose real-time camera parameter estimation method by reducing matching pairs of feature points and landmarks.
  - Reduction of feature points by estimating tentative camera parameter
  - Reduction of landmarks by selecting high prior landmarks
- Camera parameter can be estimated in large and natural environments.

Feature Work

- Verification in various environments
- Automatic initial camera parameter estimation

Thank you!!

Discussions & More information

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