Fly-through Heijo Palace Site:
Augmented Telepresence Using Aerial Omnidirectional Videos

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Goal and approach

Realizing offline augmented telepresence (AT) system in wide outdoor environment using aerial views

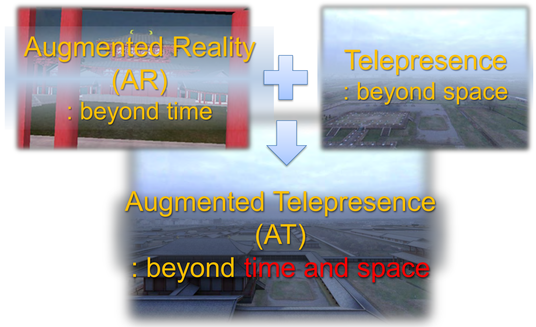
Registration problems between real and virtual worlds
- Geometric registration
- Photometric registration

are accurately resolved offline.

⇩

Space-time AT with Heijo-kyo, an old Japanese capital

CG of ancient Heijo-kyo capital
(Courtesy of Toppan Printing Co., Ltd.)

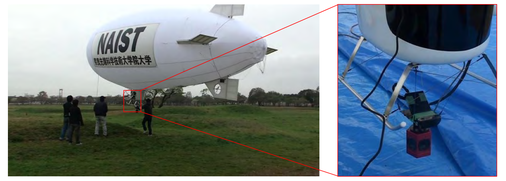


Other applications:
Map, Landscape simulation, etc.

Capturing omnidirectional video

Unmanned airship
- Length: 12m
- Payload: 15kg
- Max. speed: 50km/h

The largest battery-powered unmanned airship in the world.



Equipments
- Omnidirectional Multi-camera System (OMS) Ladybug3 (Point Grey Research, Inc.)
- Differential GPS P4-GPS (Hitachi Zosen Corp.)
- Fiber-optic gyroscope TISS-5-40 (Tokyo Keiki)

Geometric registration

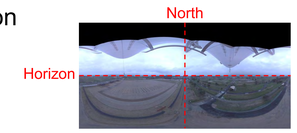
(1) Camera position and posture estimation using structure-from-motion (SfM) and GPS measurement [Yokochi, et al.]

Structure-from-motion	GPS measurement
✓Estimation process uses only video.	× Posture cannot be measured.
× Accumulative errors appear.	✓No accumulative errors appear.
× Scale factor is unknown.	✓Scale factor is acquired as GPS coordinate system.

Estimating camera position and posture without accumulative errors with scale factor.

(2) Alignment of the omnidirectional images

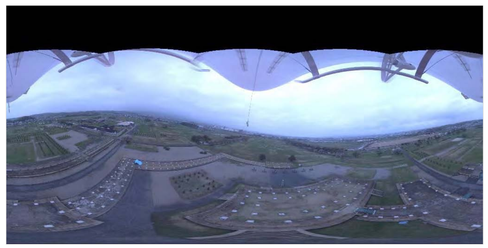
1. Omnidirectional images are mapped on a sphere.
2. The sphere is rotated by $\mathbf{R}_i^{-1} = \mathbf{R}_i^{\mathrm{T}}$.
   $\mathbf{R}_i$: Estimated posture of OMS



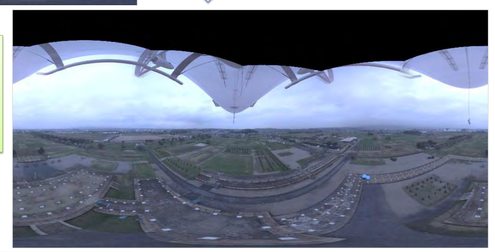
(3) Posture refinement of OMS

1. Optical-flows near the horizon of two consecutive frames on aligned video are calculated.
2. 3DOF rotation of two consecutive frames $\mathbf{R}_{\mathbf{err}}$ is estimated by minimizing an energy function defined as the sum of squares of lengths of the optical-flows mapped on the sphere.
3. $\mathbf{R}_{\mathbf{err}}^{-1} = \mathbf{R}_{\mathbf{err}}^{\mathrm{T}}$ is multiplied with posture of OMS.
4. The processes are applied to the whole sequence.

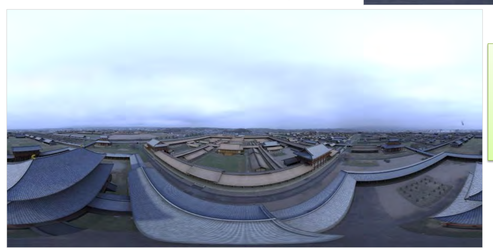
Y. Yokochi, S. Ikeda, T. Sato and N. Yokoya: "Extrinsic camera parameter estimation based-on feature tracking and GPS data," Proc. Asian Conf. on Computer Vision (ACCV2006), Vol. I, pp. 369–378, 2006.



Captured omnidirectional image



Geometric registration: Aligned omnidirectional image



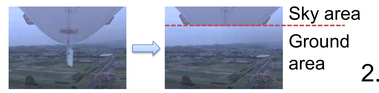
Photometric registration: Rendered augmented image

View-dependent perspective images

Photometric registration

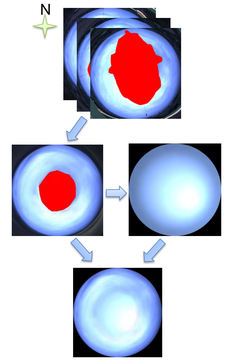
Environmental maps for Image-based-lighting (IBL) include "missing area."

(1) Completion of ground area

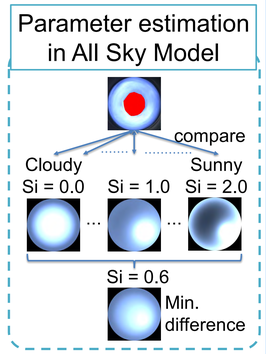


1. An area similar to the missing area is searched from previous frames using SSD criterion.
2. Intensities of corresponding pixels are copied to the missing area.

(2) Completion of sky area



1. Aligned sky images are unified in the whole sequence.
2. Parameters in All Sky Model [Igawa, et al.] are estimated from the unified image.
3. Intensities in the missing area are copied from the estimated model.



(3) Rendering augmented images

Augmented images are rendered using commercial global illumination (GI) rendering engine, 3ds Max (Autodesk, Inc.) with IBL.

N. Igawa, Y. Koga, T. Matsuzawa and H. Nakamura: "Models of sky radiance distribution and sky luminance distribution," Solar Energy, Vol. 77, pp. 137-157, 2004.