## 3D Modeling of Outdoor Environments by Integrating Omnidirectional Range and Color Images

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## 3D Models of Outdoor Scenes

Application fields
- Site simulation
- Mixed reality
- Virtual walk-through

**These models are made manually with high cost**

Virtual walk-through

Automatic 3D modeling for outdoor scenes has been widely investigated.



## Method of 3D Modeling

- **Estimating 3D shape from multiple images**
  - ○ Easy to acquire data
  - × Difficult to apply for wide area with high accuracy
- **Measuring environments by a laser rangefinder**
  - ○ Accurate range data
  - × Necessary to register multiple range data

**Using a rangefinder is suitable for accurate modeling of outdoor scenes.**



## Objective

**3D modeling of wide area outdoor scenes**

**Approach**
- **Omnidirectional sensors are used to acquire range and color images efficiently.**
- **RTK-GPS and gyroscope are used to estimate position and orientation of the sensor system.**


Sensor system on a vehicle



## Procedure of Modeling

1. Data Acquisition
   - Data are acquired at multiple points in outdoor scenes.
2. Registration of multiple range data
   - Acquired data by RTK-GPS and gyroscope are used as initial value.
   - Sensor position and orientation of range data are optimized by using improved ICP algorithm.
3. Texture-mapping of color images
   - The highest-resolution suitable texture is selected.



**Data Acquisition**

## Range and Color Image


omnidirectional range image

omnidirectional color image

Maximum measurable range approx. 200m

Measurement accuracy within 12mm

Six camera units in a camera block

More than 75% of full spherical view

Data Acquisition

## Position and Orientation

Position

RTK-GPS
(Nikon-Trimble, LogPakII)

Accuracy : approx. 3cm

Orientation

gyroscope
(TOKIMEC, TISS-5-40)

Accuracy : approx. ±2

- RTK-GPS and gyroscope are interlocked with each other.
  - Two coordinate systems are aligned automatically.
  - Accumulative error of gyroscope is corrected by measured value of RTK-GPS.
- Origin of the gyroscope coordinate system and measurement point of the RTK-GPS are considered the same point.

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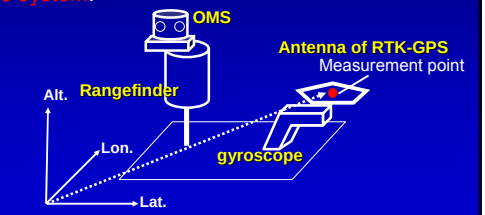
## Sensor system

- Geometrical relationships among these sensor coordinate systems are fixed.
- These coordinate systems are aligned to world coordinate system.

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## Registration of multiple range data

- Position and orientation acquired by sensors are used as initial values for registration.
- Whole data are optimized simultaneously by using ICP algorithm.
  - Many plane parts exist in outdoor environments.
  - The rangefinder can measure environment omnidirectionally.

Plane based registration by overlapping the plane parts of different range data

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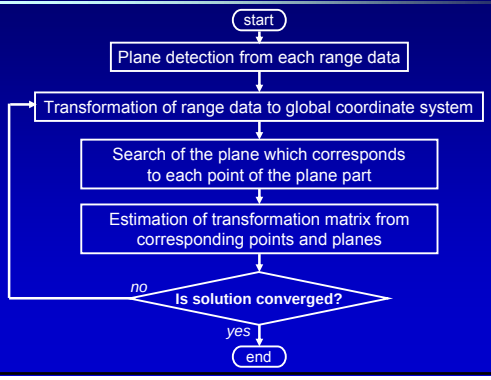
## Procedure of registering range data

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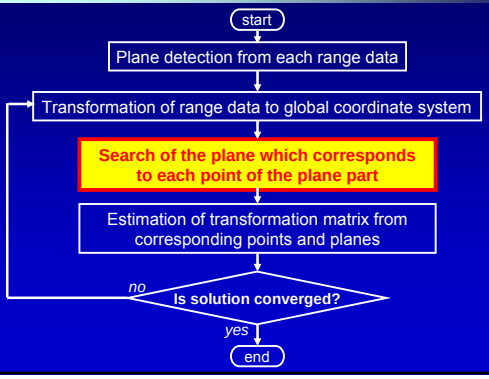
## Procedure of registering range data

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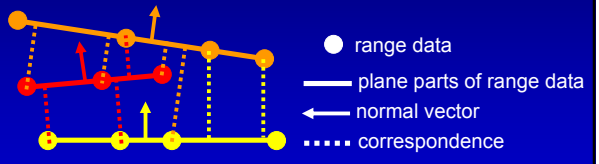
## Search of corresponding plane

The plane correspond to a point is searched from different range data.




- A plane which corresponds to the point is searched toward a normal vector direction of the plane.
- Correspondences of a point and a plane are calculated among whole data.

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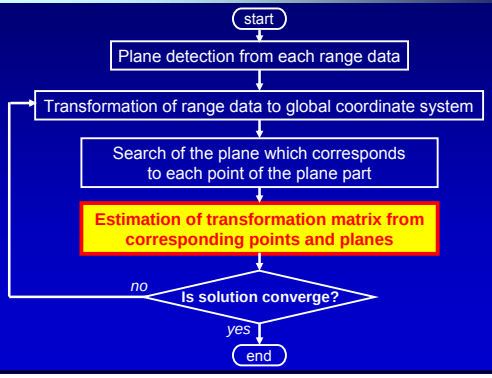
## Procedure of registering range data

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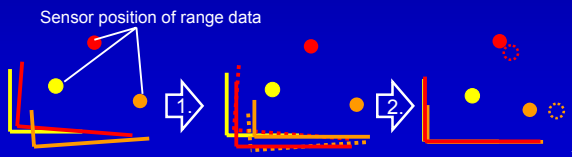
## Estimation of transformation matrix

1. Maximization of sum of Inner product of the normal vectors. (positions are fixed)
2. Minimization of sum of distance between corresponding a point and a plane. (orientations are fixed)

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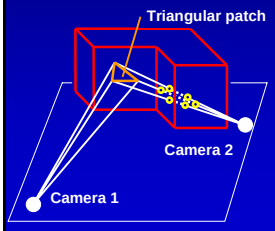
## Texture-mapping of color images

- Texture from the image which gives the highest resolution.
- Occlusions are detected from generated 3D shape.





Considering only resolution


Considering resolution and occlusion

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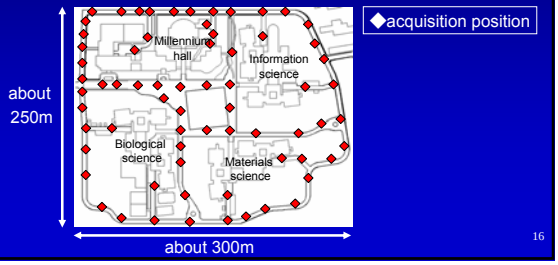
## Experiments

- Environment：our campus
- Data acquisition ：68 points (about 50m interval)
- Required time : about 5 hours

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## Result of registration

- Acquired data
  - ◆ Resolution of range image :1024 x 512
- Search process of corresponding plane
  - ◆ Use of a cluster consisting of 24 PCs (CPU: Pentium4 1.7Ghz, Memory: 1024MB)
- Optimization process
  - ◆ Use of single PC (CPU: Pentium4 1.8Ghz, Memory: 1024MB)

Required time for registration is about 7 days.

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## Result of 3D modeling

Generated model of our campus

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## 2D CAD data overlaid on generated 3D model

Generated model has no large distortion.

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## Summary

3D modeling of outdoor scenes

- Range and color images are acquired efficiently by using two omnidirectional sensors.
- Position and orientation are acquired by using RTK-GPS and gyroscope.
  - Using as initial value for registration.

Future work

- Reduction of holes (non-measured portions) of the generated model.

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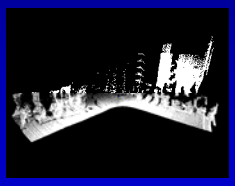
## Continuous scanning

- Continuous measurement during the movement of rangefinder.
  - The non-measured portions which exist sparsely in environment by stop-and-go scanning are measured efficiently.



integrating

+

Range data acquired by a rangefinder during movement.

Registered model from stop-and-go scanning data.

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## Approach

input

- Position and orientation of rangefinder during movement.
  + (acquired by RTK-GPS + INS sensor)
- Range data acquired during movement.

⇩ fitting

- Registered model from stop-and-go scanning data.

output

Optimized position and orientation of rangefinder during movement.

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