3D Modeling of Outdoor Scenes by Integrating Stop-and-go and Continuous Scanning

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3D Model of Outdoor Scenes

Application for ubiquitous networked media computing

- Site simulation
- Telepresence
- Mixed / Augmented reality

These models are made manually with high cost

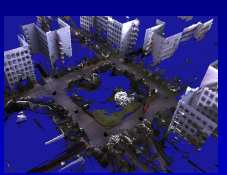
Telepresence (Virtual walk-through)

Automatic 3D modeling of outdoor scenes by using laser rangefinder has been widely investigated.

Laser rangefinder

The 3D shape of object is measured by irradiating laser beam.

Acquired partial shape



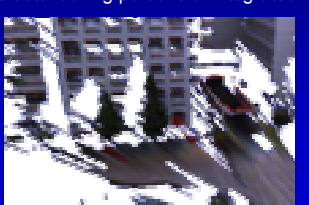
Integrated model

3D modeling of outdoor scenes by using laser rangefinder

The whole model is generated by integrating partial shapes

Non-measured portion

- The portions which are not irradiate laser beam
  - Unknown shapes
  - The data lacking portions of integrated model.



White portion : non-measured portion

Scanning method

- Stop-and-Go scanning
  - Environments are measured at fixed sensor position
  - Range data are acquired at multiple points.
    - O the rang data can be registered by matching among the data with near acquisition positions.
    - × Measurement of the environment with no non-measured portion is high cost.
- Continuous scanning
  - Environments are measured by a moving sensor.
    - O Wide area can be measured efficiently.
    - × The sensor position and orientation during measurement are needed.
      - The accuracy of generated model depend on accuracy of the estimated sensor position and orientation

Objective

3D modeling of outdoor scenes without data lacking portions

Approach

- Integration of stop-and-go and continuous scanning
  - First, the model is generated by stop-and-go scanning.
  - The portions which are not measured by stop-and-go scanning are measured by continuous scanning.

Registration of range data acquired by stop-and-go and continuous scanning

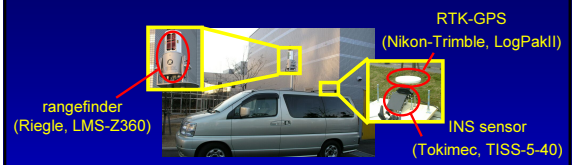
- Input
  - Generated 3D model (stop-and-go scanning).
  - Range data acquired by continuous scanning.
  - Sensor positions and orientations during continuous scanning

Registration of range data acquired by continuous scanning to the generated 3D model.

- Output
  - Optimized sensor positions and orientations during continuous scanning.

7

Sensor system of continuous scanning



Relationship among sensors is fixed

- Rangefinder (line scanner)
  - Scan rate per line is 20Hz.
- RTK-GPS + INS sensor
  - Acquisition rate of position and orientation is 50Hz.
  - Accumulative error of INS sensor can be corrected by position data acquired by RTK-GPS.

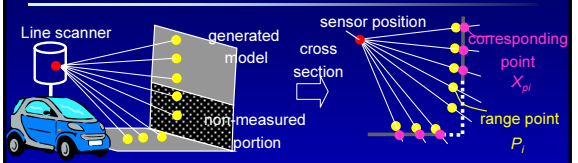
8

Procedure of registration

1. Straight lines are detected from each scan line of range data.
2. The point corresponding each point is searched from generated 3D surface model.
3. The transformation matrices are estimated by minimizing the error which defined as the sum of distances between corresponding points.

9

Estimation of transformation matrices



P_i : range point M_{Pi} : Transformation matrix of P_i to global coordinate system X_{pi} : intersection of the laser beam

Error function

$$E = \sum_{i=1}^{I} \left| (M_{pi} P_i) X_{pi} \right| \rightarrow \min$$

10

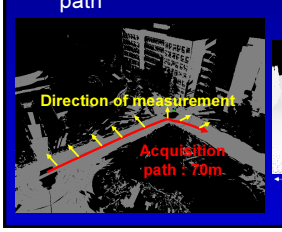
Preliminary experiments

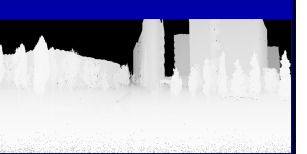
- Range data acquired by continuous scanning is registered to the model which is generated by stop-and-go scanning
  - Sensor coordinate systems are already aligned.
  - Non-measured portions are determined manually.
  - It is assumed that a line of range data is acquired in the same position and orientation.
  - It is assumed that sensor position and orientation vary smoothly.

11

Acquisition data by continuous scanning

- The model is generated by integrating 3 range data acquired by stop-and-go scanning.
- Range data of 1000 lines are acquired in the 70m path

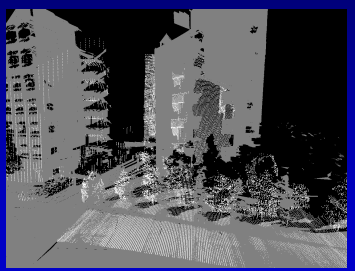




1000 line
Acquired range image

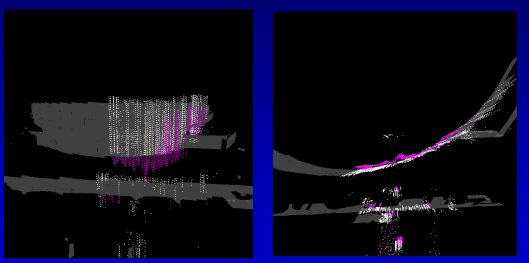
12

Experiment result (1/2)



13

Experiment result(2/2)



- generated model
- before registration
- after registration

14

Conclusion

- Integrating stop-and-go and continuous scanning
  - Registration of range data acquired by continuous scanning to the model which is generated by stop-and-go scanning.
  - We confirmed that the non-measured portions are reduced.
- Future work
  - Automation of a synchronization between the rangefinder and the INS sensor.
  - Control of the measurement direction of rangefinder for measurement of non-measured portions

15