Automatic Registration of Terrestrial Scanning Data Based on Registered Imagery

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Overview

- Introduction
- Automatic Registration Method
- Experiments & Discussion
- Summery & Outlook

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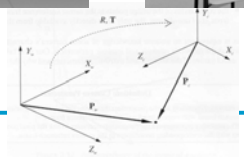
Why registration?



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Laser intensity imagery

Summary & Outlook

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Available Registration Approaches Review

Artificial marker - usually supported by the operating software of commercial terrestrial laser scanners.

Iterative Closest Point (ICP) – How to get the proximity and the establishment of correspondant point relation during each iteration are the two improtant issues.

Object-based - the determination of corresponding objects in different point clouds is a complex process.

Research needs to be carried out towards high efficiency and practicability!

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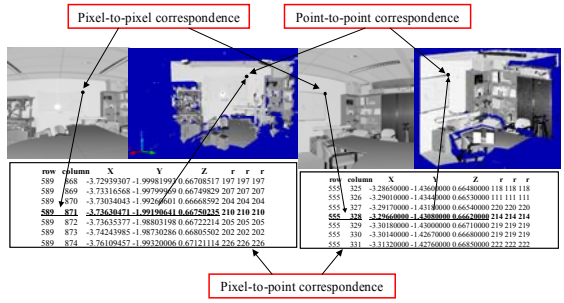
Reflectance images – 3D → 2D



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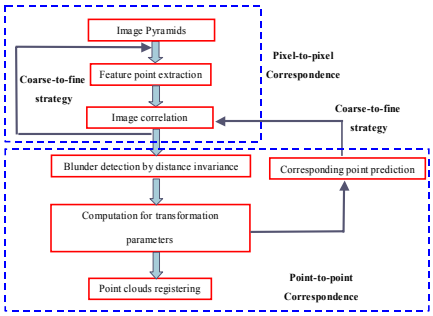
Automatic Registration – Process Overview



Automatic registration

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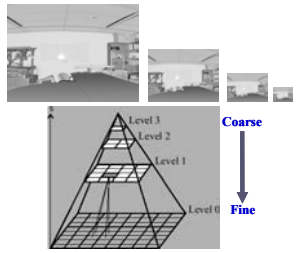
Pixel-to-pixel Correspondence – Image pyramid



The strategy of coarse-to-fine matching on image pyramid is used to increase the convergence radius.

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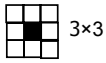
Pixel-to-pixel Correspondence – Feature point extraction

The Moravec Operator

$$M(i,j)=\frac{1}{8}\sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1}|I(k,l)-I(i,j)|$$



Since feature points have small neighborhood, raw images are divided into grids and every grid has only one feature point extracted to ensure reasonable distribution of feature points.

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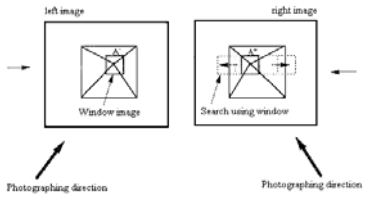
Pixel-to-pixel Correspondence – Image correlation



$$r=\frac{n\sum a_i b_i-\sum a_i\sum b_i}{\{\{n\sum a_i^{\,2}-(\sum a_i)^2\}\{n\sum b_i^{\,2}-(\sum b_i)^2\}\}^{\frac{1}{2}}}$$

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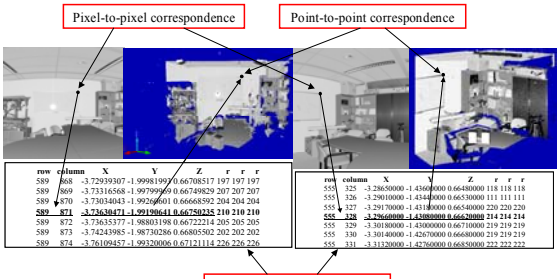
Point-to-point Correspondence



row	column	X	Y	Z	r	r	r
589	868	-3.72939307	-1.99981992	0.66708517	197	197	197
589	869	-3.73316568	-1.99799969	0.66749829	207	207	207
589	870	-3.73034043	-1.99266801	0.66668592	204	204	204
589	**871**	**-3.73630471**	**-1.99190641**	**0.66750235**	**210**	**210**	**210**
589	872	-3.73635377	-1.98803198	0.66722214	205	205	205
589	873	-3.74243985	-1.98730286	0.66805502	202	202	202
589	874	-3.76109457	-1.99320006	0.67121114	226	226	226

row	column	X	Y	Z	r	r	r
555	325	-3.28650000	-1.43660000	0.66480000	118	118	118
555	326	-3.29010000	-1.43440000	0.66530000	111	111	111
555	327	-3.29170000	-1.43180000	0.66540000	220	220	220
555	**328**	**-3.29660000**	**-1.43080000**	**0.66620000**	**214**	**214**	**214**
555	329	-3.30180000	-1.43000000	0.66710000	219	219	219
555	330	-3.30140000	-1.42670000	0.66680000	219	219	219
555	331	-3.31320000	-1.42760000	0.66850000	222	222	222

Point-to-point

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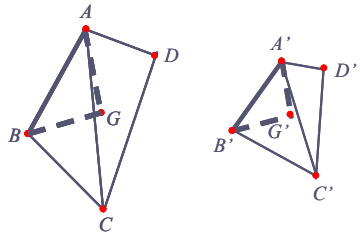
Outlier detection by distance invariance



$$|S_{AB}-S_{A'B'}|<3\sigma_{DI}$$

which point is wrong if a pair does not satisfy?

Point-to-point

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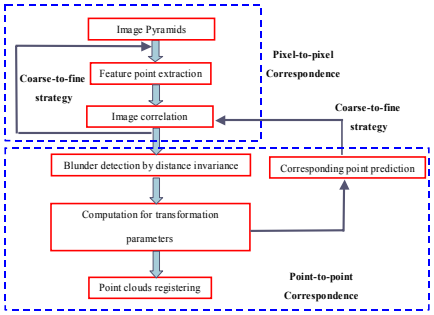
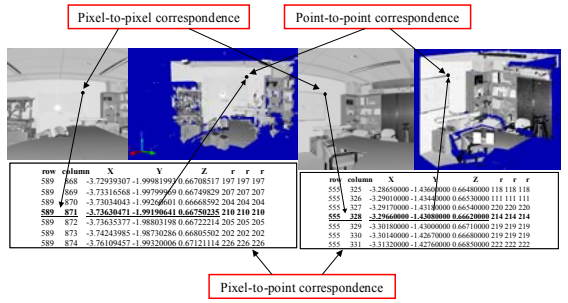
Registration process overview



Corresponding point prediction



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Experiments & Discussion

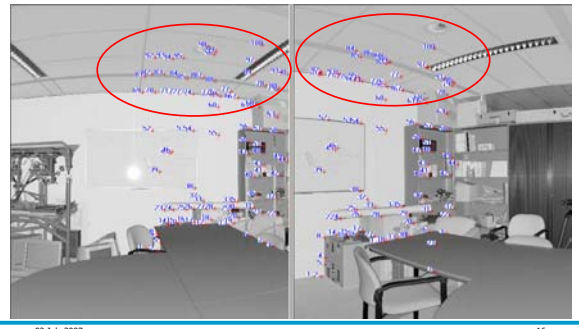
Dataset 1

Dataset 2

Point cloud	Angular resolution		Angular accuracy	Range accuracy	Image Angular resolution
	Horizontal	Vertical			
Dataset 1~2	0.036°	0.036°	18μm+3μm/m	±3mm	0.036°

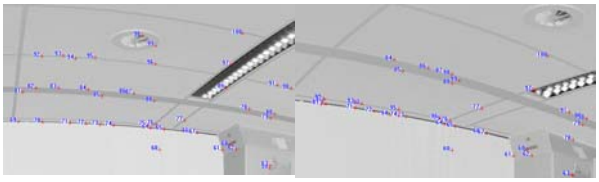
Dataset 1

Initial corresponding points



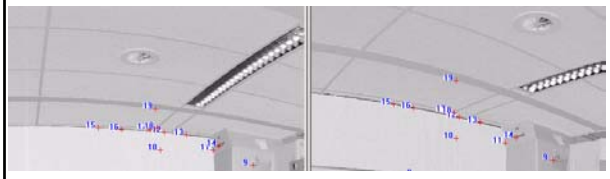
Dataset 1

Initial corresponding points



Dataset 1

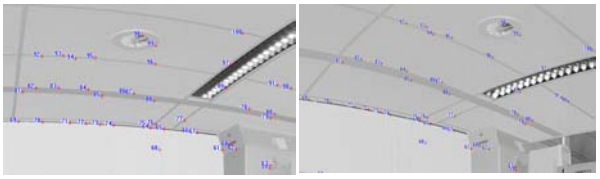
Blunder detection by distance invariance



Threshold: σ_{DI}

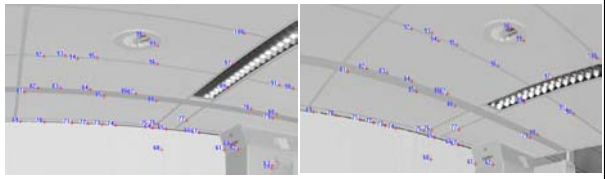
Dataset 1

Iterative process



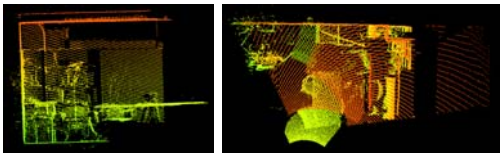
Dataset 1

Blunder detection by distance invariance



Threshold: $3\sigma_{DI}$

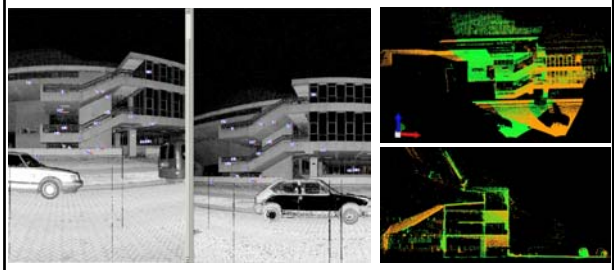
Dataset 1



Result comparison

Dataset 1	n_1 n_2	i	RMS (m)	Max (m)	Min (m)	AVG (m)	Time (min)
Cyclone 5.5	2054987 2054987	37	0.0072	0.0960	5.678e-009	0.0033	6
Presented Method	2054987 2054987	2	0.0063	0.0432	0.0012	0.0085	0.5

Dataset 2



21 corresponding point pairs are matched.

Dataset 2

Result comparison

Dataset 2	n_1 n_2	i	RMS	Max	Min	AVG	Time (min)
Cyclone 5.5	1785112 1716040	74	0.0081	0.1530	3.532e-008	0.0056	7
Presented method	1785112 1716040	4	0.0088	0.0310	0.0062	0.0132	0.8

Compared to ICP method, the accuracies are compatible, i.e. both of the accuracies are in the order of millimetres. The major difference is in the automation level, performance and the number of iterations.

Summary

Although at initial stage, the performed tests revealed several advantages :

- **A completely automatic process**
- **Applicable for any laser scanner that can output reflectance images**
- **Much faster compared to ICP method**
- **Distance invariance and iterative point-to-point corresponding process allow for improving the registering accuracy**

Outlook

Future work will concentrate on:

- More aspects of laser scanner accuracy, e.g. resolution, edge effects, etc. should be considered to estimate the distance invariance error.
- The approach should be adapted to deal with panoramic reflectance imagery so that 360° full scans can be registered.