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VICENZA - ITALY

Using Multicore Processors to Parallelize 3D Point Cloud Registration with the Coarse Binary Cubes Method

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1.
INTRODUCTION

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3D point cloud matching

- It is a basic operation in mobile robotics for localization and mapping.
- All scan directions and depths may contain relevant data. Farther regions have lower sampling densities.
- The search is performed around an initial odometric estimation.

Aim of this work

• To speed up 3D point cloud matching with the Coarse Binary Cubes (CBC) method

by taking advantage of widespread multicore and multithreaded processors.

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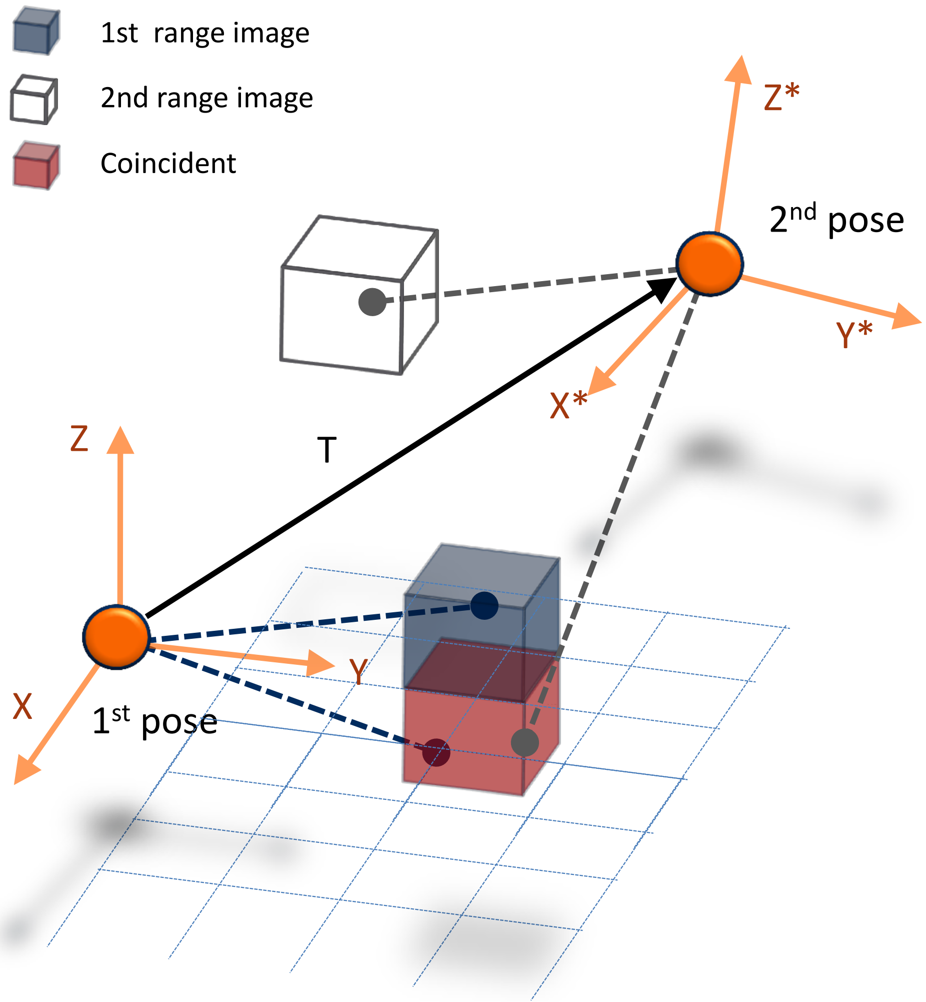
2.
THE COARSE BINARY CUBES (CBC) METHOD

Illustration of the CBC principle



- *Which is the spatial transformation*

$$\mathbf{T} = [x_0, y_0, z_0, \alpha, \beta, \gamma]$$

to project the second scan into the first scan that maximices the number J of coincident binary cubes?

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The CBC method

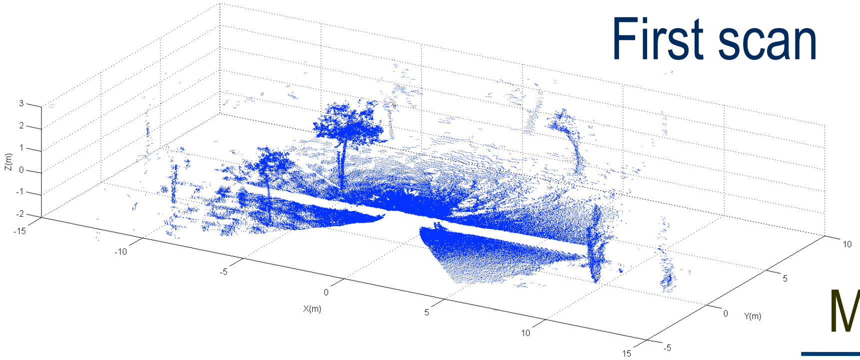
- *Objective function J(T)* can be evaluated:
  - without using any 3D data structure,
  - in *O(n)* time, where *n* is the number of points.

- The search for *T* is performed with a variation of the Nelder-Mead method:
  - Instead of a simplex of 7 vertices, $m \gg 7$ vertices are used.
  - Shrinking the set of vertices is avoided and the set is reinitialized around the initial estimation.

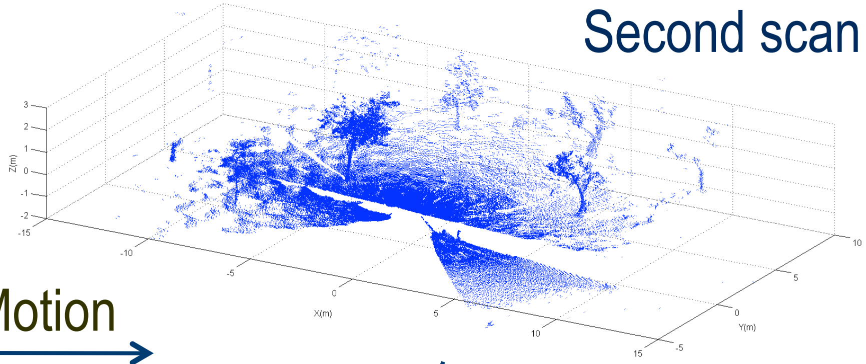
- CBC is a compelling alternative to Iterative Closest Points (ICP) and Normal Distribution Transform (NDT) for scene registration (Martínez et al., 2012).

Example of a match for outdoor scene

First scan

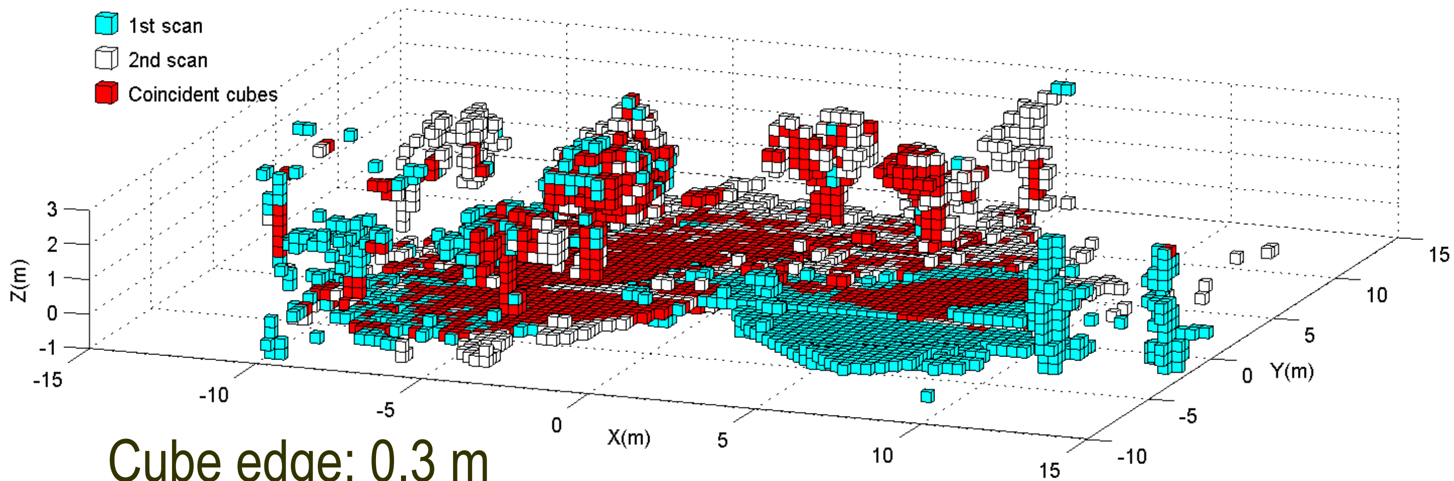


Second scan



Motion

T



Cube edge: 0.3 m

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3.
CBC FOR MULTICORE PROCESSORS

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Parallelization alternatives

1. To broke down the computation of *J* into independent tasks to be evenly spread across the cores.

   - It requires semaphores to share data structures.

2. To evaluate different prospective solutions *J(T)* in parallel by replacing the *p* worst vertices.

   - This strategy is suitable as long as $p<m$.

   - Easily scalable to the available cores without rewriting code.

   - Replacement of a vertex requires 2 *J* evaluations: reflection and (expansion or contraction).

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4.
EXPERIMENTAL RESULTS

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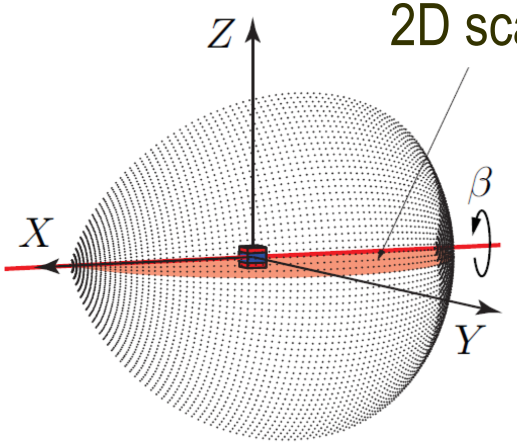
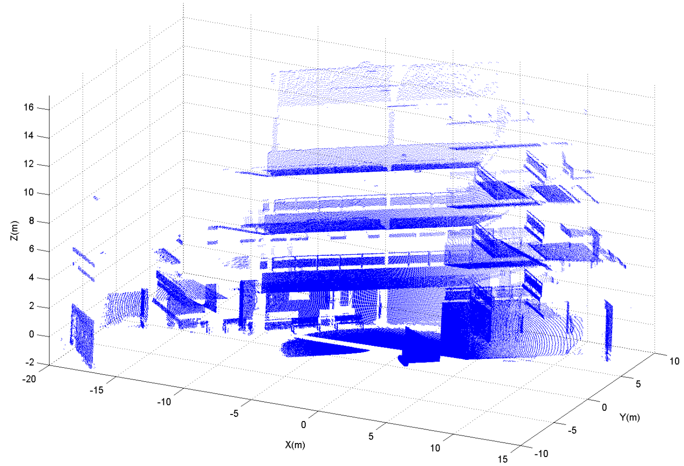
Experimental setup



Indoor scene

3D laser device



Point cloud: n= 505.036 points,
Maximun range: 30 m

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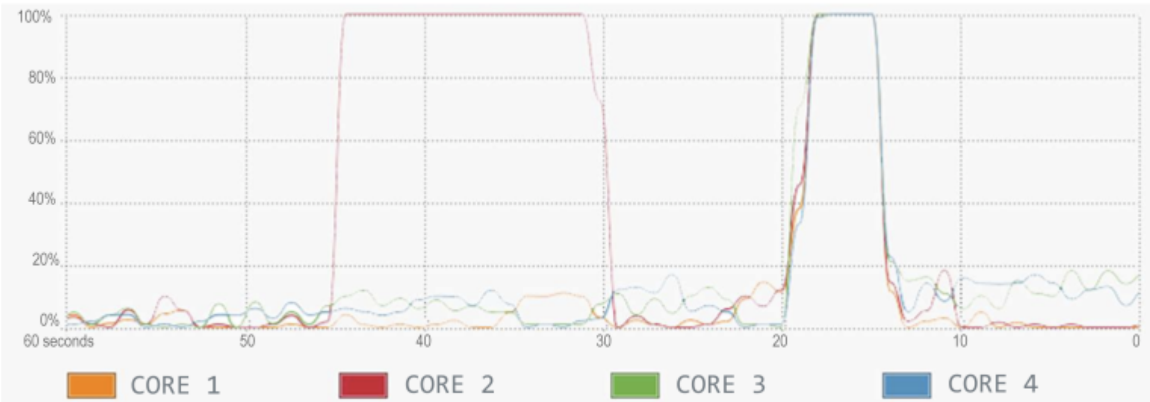
Registration results (Linux OS,OpenMP library,m= 22)

Scene	J for the ground truth	ℓ	p	E_s (m)	E_a (°)	Number of evaluations	J	Time (s)	g
Indoor	8857	12381	1	0.010	0.003	802	8906	21.16	1.0
			2	0.008	0.003	802	8912	10.52	2.0
			4	0.008	0.003	802	8908	5.76	3.7
			6	0.009	0.002	810	8901	7.28	2.9
Outdoor	2631	4123	1	0.031	0.005	1303	2653	14.32	1.0
			2	0.026	0.005	1300	2657	7.04	2.0
			4	0.042	0.007	1306	2642	3.76	3.8
			6	0.069	0.010	1306	2628	4.84	3.0



Processor: Intel Core Quad Q9550 (4 cores)

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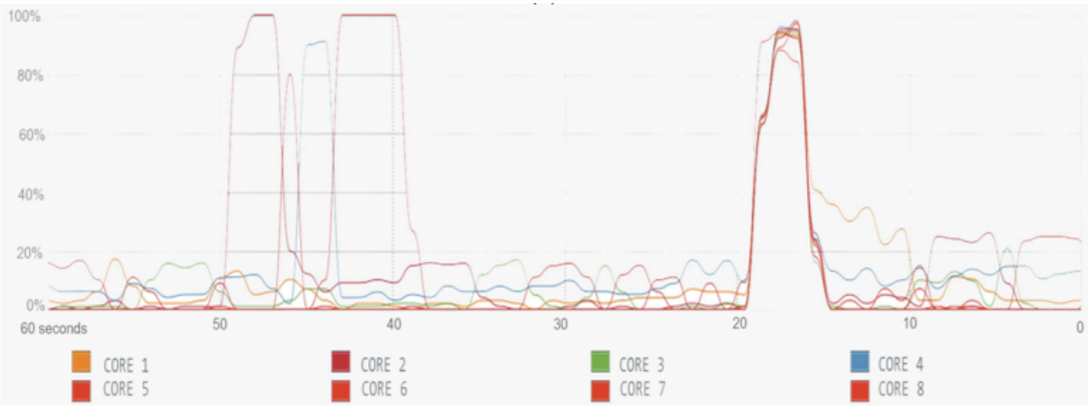
Registration results (Linux OS,OpenMP library,m=28)

Scene	J for the ground truth	ℓ	p	E_s (m)	E_a (°)	Number of evaluations	J	Time (s)	g
Indoor	8857	12381	1	0.007	0.003	807	8912	14.52	1.0
			2	0.050	0.003	803	8809	7.44	2.0
			4	0.064	0.003	806	8803	6.68	2.2
			6	0.010	0.003	809	8898	5.32	2.7
			8	0.011	0.003	806	8901	4.04	3.6
			10	0.010	0.003	810	8886	6.44	2.3
Outdoor	2631	4123	1	0.052	0.010	1305	2640	9.68	1.0
			2	0.030	0.006	1302	2649	5.20	1.9
			4	0.025	0.005	1308	2656	5.02	1.9
			6	0.037	0.006	1308	2650	3.80	2.5
			8	0.056	0.010	1307	2637	2.80	3.5
			10	0.057	0.009	1314	2631	3.60	2.7



Processor: Intel Core i7 2720QM (8 virtual cores)

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5.
CONCLUSIONS

Conclusions

- The efficiency of Coarse Binary Cubes (CBC) method has been improved by using multicore processors.
- Prospective solutions has been evaluated in parallel in the Nelder-Mead search by replacing the *p* worst vertices.
- A gain *g* near to the number of physical cores have been achieved without degrading registration accuracy.
- Future work:
  - Subsample the scan to reduce the number of points to be projected *n*.
  - Parallelize CBC with a Graphic Processing Unit (GPU).

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Thank you!