Performing patient alignment utilising point-cloud surface registration techniques in HoloNav

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1 Introduction

- Traditional surgical navigation systems display navigation info on a screen

HoloNav project:

- Microsoft HoloLens as a surgical navigation device
- Use AR to show navigation data on the patient itself

2 Problem

- Surgical navigation requires accurate alignment of pre-operative scan with patient

Research question:

- *"How can we perform patient alignment using point-cloud surface registration algorithms?"*

Problem with registration algorithms:

- They require similar and dense source and target point clouds
- Not the case in this scenario

- Target data

- Source data

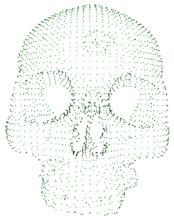
3 Method

- HoloLens depth sensor used to get detailed target point cloud
- Data unavailable → simulate from pre-operative scan

Data simulation:

- Add noise, occlusion and sparsity

- Noise



- Sparsity

- Occlusion

Test different algorithms for rough point cloud alignment:

- Fast Point Feature Histograms (FPFH) [1]
- Principal Component Analysis (PCA) [2]
- Manual Point Matching

Use Iterative Closest Point (ICP) algorithm [3] for fine alignment

4 Results

Performance of the algorithms:

- PCA more resilient to noise than PFFH

Noise amount	FPFH	PCA
0	1.3434	1.3434
0.5	1.3402	1.34949
1	1.47238	1.32688
...	...	...
4.5	0.88746	1.13068
5	322.1151	1.12898
5.5	2505.255	1.1059
6	5.74996	1.1059

- Alignment error in mm after rough and fine alignment on simulatied data. Results in red indicate failed alignments.

- FPFH outperforms PCA in all other cases (sparsity and occlusion)

Occlusion Angle	FPFH	PCA
0°	1.10841	1.13809
5°	1.1129	2460.321
10°	1.08763	1.15165
15°	1.06005	2488.618
20°	1.03576	1.10652
...	...	...

Points	FPFH	PCA
29613	1.11036	2672.057
8263	1.12713	2439.068
...	...	...
784	1.23063	2507.812
600	7887.997	3815.588
472	1.09453	2087.251
384	2109.046	2809.095

- Alignment error in mm after rough and fine alignment on simulatied data. Results in red indicate failed alignments..

Best results with manual point matching:

- Perfect alignment with 4+ matched points
- Surgeon inaccuracy has little impact on the performance

5 Conclusion

- Performance depends on quality inuput data
- ICP is able to recover less accurate rough alignments

6 Future work

- Perform research with actual depth sensor data
- Research methods to extract patient from the rest of the 3D scene

References
[1] Rusu, R. B., Blodow, N., & Beetz, M. (2009). Fast Point Feature Histograms (FPFH) for 3D registration. 2009 IEEE International Conference on Robotics and Automation, 3212–3217. https://doi.org/10.1109/ROBOT.2009.5152473
[2] Tian, H., Dang, X., Wang, J., & Wu, D. (2017). Registration method for three-dimensional point cloud in rough and fine registrations based on principal component analysis and iterative closest point algorithm. Traitement Du Signal. https://doi.org/10.3166/TS.34.57-75
[3] Wang, F., & Zhao, Z. (2017). A survey of iterative closest point algorithm. 2017 Chinese Automation Congress (CAC), 4395–4399. https://doi.org/10.1109/CAC.2017.8243553

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