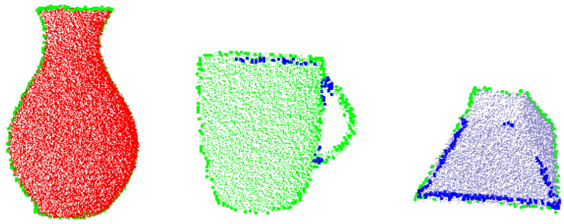

(c)

**Figure 5:** Coarse pose estimation using LGFs. (a) 3D model of the scene. (b) Point cloud with noise. (c) Detected feature points in the segmented point clouds

The square frustum is used to verify the efficiency of CEF. The pose matrices of the matched CEF in the scene point cloud and the 3D model are

$$T_{frust,scene} = \begin{bmatrix} 0.080 & -0.930 & -0.359 & 0.517 \\ 0.927 & 0.202 & -0.317 & 0.102 \\ 0.367 & -0.308 & 0.878 & -3.000 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (10)$$

$$T_{frust,refer} = \begin{bmatrix} 0.065 & -0.924 & -0.378 & 0.526 \\ 0.933 & 0.190 & -0.305 & 0.080 \\ 0.354 & -0.332 & 0.874 & -3.007 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (11)$$

Position error is $p_{frust,error} = [-0.011 \quad 0.022 \quad 0.007]^T \, m$. Orientation error is represented using axis angle of rotation matrix [13]. The rotation angle from the coordinate frame in the reference model to that in the scene point cloud is $\theta_{frust,error} = 1.5^\circ$. Compared to CNF, the position and orientation error in CEF is much smaller [14].

## 5. CONCLUSIONS

In this paper, we present two kinds of local geometric features (LGFs) for coarse pose registration. The proposed LGFs utilize the geometric information to define coordinate frames on the estimated objects. Pose registration is performed by calculating the transformation between the frames of the matched LGFs in the scene point cloud and the reference 3D model. How to construct these two LGFs, i.e. corner edge feature (CEF) and circle normal feature (CNF), are introduced. The pipeline of coarse registration using LGFs is presented. Simulation is done and verifies LGFs' feasibility. The simulation results also indicate that the registration error is affected by the estimation accuracy of the parameters of 3D lines and circles. To conquer this, in future work we will optimize RANSAC algorithm so that it can reduce estimation error.

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**REFERENCES**

[1] Aldoma, A., Marton, Z.-C., Tombari, F., Wohlkinger, W., Potthast, C., Zeisl, B., Vincze, M. 2012. Tutorial: Point cloud library: Three-dimensional object recognition and 6 dof pose estimation. IEEE Robotics and Automation Magazine, 19 (3), 80-91.

[2] Diez, Y., Roure, F., Lladó, X., Salvi, J. 2015. A qualitative review on 3d coarse registration methods. ACM Computing Surveys (CSUR), 47 (3), 45.

[3] Sipiran, I., Bustos, B. 2011. Harris 3D: A robust extension of the Harris operator for interest point detection on 3D meshes. The Visual Computer, 11 (2), 963-976.

[4] Wohlkinger, W., Vincze, M. 2011. Ensemble of shape functions for 3-D object classification, in IEEE Int. Conf. Robotics and Biomimetics (IEEE-ROBIO), 2987-2992.

[5] Cornea, N.D., Silver, D., Min, P. 2007. Curve-skeleton properties, applications, and algorithms. IEEE Transactions on Visualization and Computer Graphics, 13 (3), 530-548.

[6] Rusu, R. B., Blodow, N., Beetz, M. 2009. Fast point feature histograms (FPFH) for 3-D registration, in IEEE Int. Conf. Robotics and Automation (ICRA), Kobe, Japan, 3212-3217.

[7] Tombari, F., Salti, S., Stefano, L. 2010. Unique signature of histograms for local surface description, in Proc. 11th European Conf. Computer Vision (ECCV '10), 356–369.

[8] Armenise, V. 2013. Estimation of the 3D Pose of objects in a scene captured with Kinect camera using CAD models. School of Computer Science and Communication.

[9] Bischof, Horst, Leonardis, A., Selb, A. 1999. MDL Principle for Robust Vector Quantisation. Pattern Analysis and Applications, 1 (2), 59-72.

[10] Besl, P. J., McKay, N. D.1992. A method for registration of 3-D shapes. IEEE Transactions on Pattern Analysis and Machine Intelligence, 14 (2), 239-256.

[11] Gumhold, S., Wang, X., MacLeod, R. S. 2001. Feature Extraction From Point Clouds. In Proceedings of the 10th International Meshing Roundtable.

[12] Gschwandtner, M., Kwitt, R., Uhl, A., Pree, W. 2011. BlenSor: Blender Sensor Simulation Toolbox. Advances in Visual Computing, 199-208.

[13] Shuster, M. D. 1993. A survey of attitude representations. Navigation, 8 (9), 439–517.

[14] Fischler, M. A., Bolles, R. C. 1981. Random sample consensus : a paradigm for model fitting with applications to image analysis and automated cartography. Communications of the ACM, 24 (6), 381-395.