Chair of Computing in Civil and Building Engineering
TUM Georg Nemetschek Institute – AI for the Built World
Technical University of Munich

Master Thesis Proposal

Deep Learning-Based Detection of Machining Features and Tools from CAD-Derived Point Cloud Data

Description

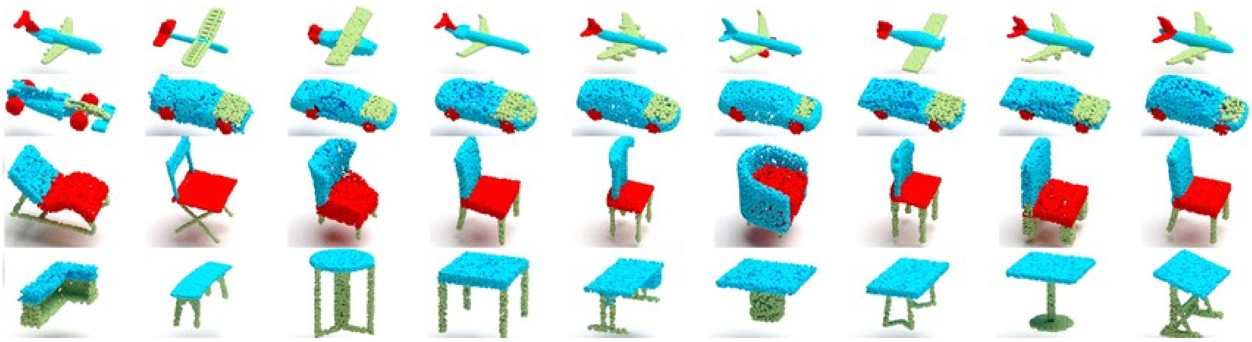
The need for automated, intelligent Computer-Aided Manufacturing (CAM) is intensifying due to rapidly increasing demands for customized and complex products. One crucial capability for next-generation CAM is the accurate detection of machining features, tools, and processes directly from 3D data, such as point clouds generated from CAD models. Conventional rule-based systems struggle to generalize across the vast variability found in modern engineering parts, motivating a shift toward data-driven, learning-based approaches.

Recent deep learning advances in point cloud segmentation have yielded powerful architectures, such as PointNet++, DGCNN, KPConv, Point Transformer, and Point-Voxel Transformer (PVT) that can learn rich geometric representations from raw 3D data.

However, benchmarking and adapting these for the specific manufacturing challenge of recognizing machining features (e.g., holes, slots, pockets) and inferring tool/process information remains an open research problem.

This thesis will:

- Develop and benchmark deep learning approaches for automatic machining feature and tool/process detection from point clouds originating from CAD models.
- Compare state-of-the-art segmentation architectures, indicatively:
    - PointNet++,
    - DGCNN,
    - KPConv,
    - Point Transformer,
    - PVT.
- Leverage large, open datasets such as MFCAD, ABC, and Fusion360 Gallery for comprehensive development and evaluation.



Key tasks

- Survey and selection of point cloud segmentation methods** suitable for manufacturing feature detection.
- Adaptation of architectures to classify and segment machining-relevant classes from 3D CAD data.
- Dataset curation and preprocessing: Conversion of CAD models to point clouds, annotation of features, and preparation of training/validation splits.
- Quantitative comparison of methods against machining-relevant metrics (e.g., segmentation IoU, feature/class detection accuracy).
- Case study analysis on complex or industrially relevant parts to assess real-world applicability.

You have

- strong programming skills (Python),
- background in machine learning
- research mindset
- analytical thinking,
- problem-solving abilities,
- writing skills

Supervisors

Stavros Nousias (stavros.nousias@tum.de),

Open Datasets

MFCAD	Andrew R. Colligan, Trevor T. Robinson, Declan C. Nolan, Yang Hua, and Weijuan Cao. Hierarchical cadnet: Learning from b-reps for machining feature recognition. Computer-Aided Design, 147:103226, 2022.
ABC Dataset	Koch, S., Matveev, A., Jiang, Z., Williams, F., Artemov, A., Burnaev, E., Alexa, M., Zorin, D. and Panozzo, D., 2019. Abc: A big cad model dataset for geometric deep learning. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 9601-9611).
Fusion360 Gallery	Willis, K. D., Pu, Y., Luo, J., Chu, H., Du, T., Lambourne, J. G., Solar-Lezama, A., & Matusik, W. (2021). Fusion 360 Gallery: A dataset and environment for programmatic CAD construction from human design sequences. *ACM Transactions on Graphics*, 40(4), 1-24. https://doi.org/10.1145/3450626.3459818

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Thomas, H., Qi, C.R., Deschaud, J.E., Marcotegui, B., Goulette, F. and Guibas, L.J., 2019. Kpconv: Flexible and deformable convolution for point clouds. In *Proceedings of the IEEE/CVF international conference on computer vision* (pp. 6411-6420).

Zhao, H., Jiang, L., Jia, J., Torr, P.H. and Koltun, V., 2021. Point transformer. In *Proceedings of the IEEE/CVF international conference on computer vision* (pp. 16259-16268).

Zhang, C., Wan, H., Shen, X. and Wu, Z., 2022. PVT: Point-voxel transformer for point cloud learning. *International Journal of Intelligent Systems*, *37*(12), pp.11985-12008.