Technical University of Munich
TUM School of Engineering and Design
Chair of Computational Modeling and Simulation

Master Thesis Proposal

Reinforcement Learning for Segmentation Analysis and Assembly of CAD Models

Background

Computer-Aided Design (CAD) plays a crucial role in modern engineering, enabling the creation of complex digital models. Efficiently analyzing and segmenting these CAD models into their component parts is essential for applications in manufacturing, assembly automation, and quality control. Recent advances in machine and deep learning facilitated feature extraction, segmentation, part classification, reverse engineering and assembly related operations. However, often, even advanced machine learning methods require large datasets to be effectively trained.

Reinforcement Learning (RL) has emerged as a promising solution, significantly reducing the data required to achieve effective model segmentation and assembly. Unlike traditional supervised methods that require vast amounts of labeled data, RL leverages experience and interaction within a virtual environment to autonomously learn optimal strategies.

By researching Reinforcement Learning oriented methods, this thesis aims to develop a method for the reverse engineering of CAD models based on the Fusion360 dataset modalities, namely segmentation and assembly, focusing on the utilization of limited number of training examples.

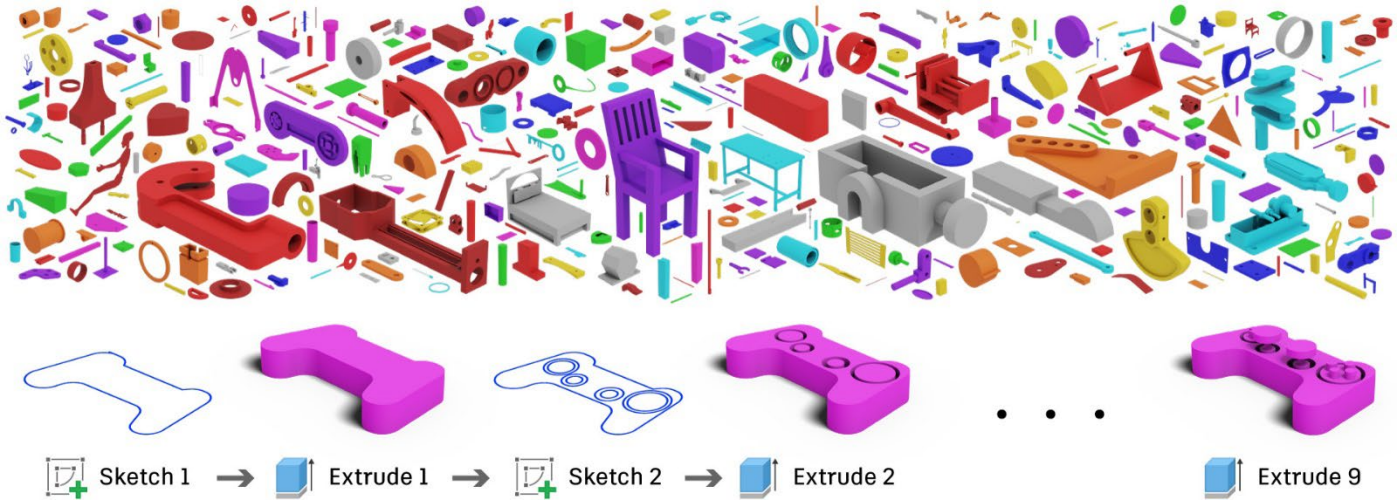

Figure 1 Sequential construction sequence information from a subset of simple 'sketch and extrude' designs. Source : https://github.com/AutodeskAILab/Fusion360GalleryDataset

Objective

This research-oriented thesis will investigate how state-of-the-art RL algorithms, (such as Q-learning, Deep Q Networks, and Policy Gradient methods), can be applied to CAD model segmentation and assembly, using the 360 Fusion Dataset. The thesis aims towards the **development of a method** that leverages reinforcement learning to automatically determine the optimal reconstruction and assembly sequence for CAD models and CAD composites.

Task

1. **Literature Review**: Conduct a comprehensive review of state-of-the-art methods in CAD model segmentation and assembly, with a particular focus on RL-based techniques.

2. **Methodology Identification**: Identify suitable RL algorithms and configurations for segmentation and assembly tasks, exploring different reward structures, policy strategies, and model architectures.

3. **Data Preparation**: Deploy the 360 Fusion Dataset for segmentation and assembly.

4. **Implementation**: Develop and implement an RL framework for segmentation and assembly tasks, utilizing neural network architectures compatible with deep RL frameworks (e.g., Pytorch, Tensorflow).

5. **Experimental Evaluation**: Compare RL-based segmentation and assembly results against traditional methods on accuracy, speed, and adaptability metrics.

You Have

- Python programming.
- Knowledge of CAD software and data preprocessing techniques.
- Familiarity with RL concepts and motivation to work with deep learning frameworks such as Pytorch, Tensorflow, or Keras.

Supervision

Stavros Nousias, PhD

Konstantinos Gkrispanis MSc.

References

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2. Li, P., Guo, J., Zhang, X. and Yan, D.M., 2023. Secad-net: Self-supervised cad reconstruction by learning sketch-extrude operations. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 16816-16826).

3. Willis, K.D., Pu, Y., Luo, J., Chu, H., Du, T., Lambourne, J.G., Solar-Lezama, A. and Matusik, W., 2021. Fusion 360 gallery: A dataset and environment for programmatic cad construction from human design sequences. *ACM Transactions on Graphics (TOG)*, *40*(4), pp.1-24.