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 Segmentation on CAD models with Mesh driven features

Description

Efficient and reliable segmentation of 3D mesh data is pivotal in engineering, CAD/CAM, and digital manufacturing. Traditional rule-based techniques often struggle with the diversity and complexity of modern product geometries. Deep learning approaches, capable of directly processing mesh structures, have recently enabled data-driven extraction of meaningful parts and features relevant for design, analysis, and manufacturing automation.

This thesis aims to investigate, implement, and benchmark state-of-the-art deep learning methods for mesh segmentation in the context of engineering CAD data. The focus will be on evaluating their effectiveness, robustness, and computational performance in realistic mesh analysis scenarios.

The first stage involves a comprehensive survey of recent developments in deep mesh segmentation methodologies. Subsequent work will consist of the implementation of selected state-of-the-art neural network architectures, namely SubdivNet, DiffusionNet, HodgeNet, and MeT. To ensure rigorous testing, a dedicated dataset will be crafted by converting CAD models into meshes using different remeshing strategies, with a range of resolutions represented. Each segmentation method will be evaluated using recognized quantitative metrics, such as Intersection-over-Union, segmentation accuracy, and computational efficiency. Throughout the investigation, special attention will be paid to the limitations, scalability, and adaptability of these approaches for practical applications within the manufacturing and engineering CAD context.

Three categories of datasets will illustrate core experimental scenarios. The COSEG dataset provides a rich array of labelled mesh parts for semantic segmentation, while SHREC serves as a benchmark for particularly challenging mesh segmentation activities. To further evaluate method robustness, a collection of custom engineering CAD models will be created, each remeshed at multiple resolutions.

Expected outcomes include a thorough comparison of leading deep learning models for mesh segmentation on engineering-focused data, a detailed assessment of accuracy, efficiency, and practical relevance within CAD/CAM settings, and clear guidance detailing best practices for the integration of mesh segmentation workflows in industrial design and manufacturing automation.

Key Tasks

1. Survey deep mesh segmentation methods.
2. Implement selected architectures: SubdivNet, DiffusionNet, HodgeNet, and MeshCNN.
3. Prepare a dedicated dataset by converting CAD models into meshes using various remeshing techniques at different resolutions.
4. Quantitatively compare the selected methods using standard metrics such as Intersection-over-Union (IoU), segmentation accuracy, and computational efficiency.
5. Analyze limitations, scalability, and potential adaptations for applications in manufacturing and engineering CAD.

Example Datasets

- COSEG: Diverse, labeled mesh parts for semantic segmentation.
- SHREC: Benchmark for challenging mesh segmentation scenarios.
- Custom CAD Meshes: Engineering-focused models, remeshed at varying resolutions.

Expected Outcomes

- In-depth comparison of leading mesh segmentation deep learning models on engineering-relevant data.
- Evaluation of accuracy, computational efficiency, and applicability in real CAD/CAM settings.
- Guidance and best practices for applying mesh segmentation in design and manufacturing automation workflows.

You have

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

Supervisors

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References

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