Rapport de Stage de fin d'étude

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Titre

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Chapitre 1

Introduction

1.1 D3S, a leader in 3D CAD Analytics

D3S, which stands for Data Science Softwares & Services, specializes in delivering customized software solutions utilizing AI technologies. The company comprises a team of Data Scientists and Full Stack Developers with deep expertise in 3D CAD (Computer-Aided Design) Analytics and Natural Language Processing (NLP).

Its state-of-the-art technologies are built on open-source libraries and supported by internal R&D, enabling efficient data extraction through computer vision, Optical Character Recognition (OCR), and NLP. D3S also excels in deep learning applications such as 3D morpho analysis, metrics comparison, BoM (Bill of Materials) analytics, and time series processing.

The company's solutions are designed to provide scalable, adaptable, and secure business value for industries like aerospace and automotive.

I will be working with the 3D CAD Analytics team, where my focus will be on developing a 3D similarity model designed to compare CAD models solely based on their geometric properties.

FIGURE 1.1 – D3S, Data Science Softwares & Services

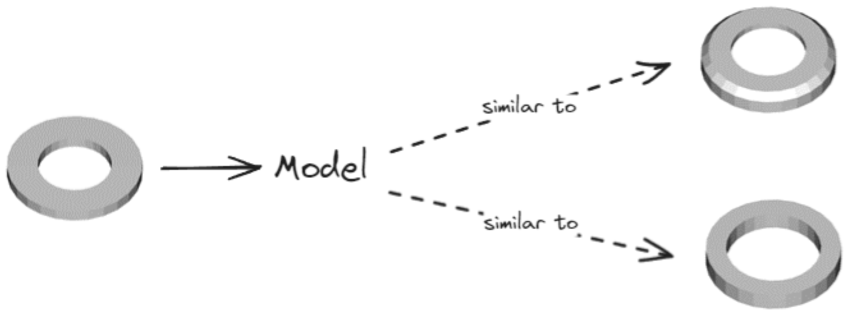

FIGURE 1.2 – Purpose of our similarity model

1.2 3D similarity model

3D model designers spend a significant amount of time searching for relevant information during the product design process, even though much of their work could be done by modifying existing Computer-Aided Design (CAD) models. As a result, the retrieval and reuse of CAD models are crucial in CAD model management. However, large CAD model repositories often require extensive categorization or organization of engineering data, making design reuse challenging. Traditionally, the classification and retrieval of 3D CAD models involved a manual process of labeling, which is time-consuming, prone to errors, and inefficient. This issue becomes even more pronounced when models are generated in product development, as inconsistent labeling and tagging across different systems lead to the complex task of data harmonization. Additionally, the inherent complexity of 3D CAD model definitions makes it difficult to apply rigid, general classification rules, as model features and parameters vary depending on their origin. Therefore, an automated approach to classification and retrieval is needed to address these challenges.

The goal is to automatically associate a given piece to similar other pieces, as depicted in figure 1.2. This will make it possible to leverage the D3S dataset of industrial 3D models, in order to infer missing information, such as the name of a piece, its function, or its material.

In recent years, point cloud representations has become one of the research hotspots in the field of computer vision [13]. In our case, we can not directly train a powerful classifier, because of a lack of clean labeled data and of the variety of the possible 3D models. The most comprehensive dataset available consists of just 2,000 CAD models, with rather imprecise labeling. Examples of labels include coupling strap, shackle, and long beam. It is evident that there is a significant need for a more curated and accurate dataset in this area, which is really hard to obtain.

Given the recent success of self-supervised learning methods, more specifically contras-

FIGURE 1.3 – Pipeline for building the model

tive learning [6, 12, 4], an innovative and promising approach has been proposed to tackle this problem.

The goal is to learn a representation of data such that similar instances are close together in the representation space, while dissimilar instances are far apart. To do so, a triplet loss, popularized by the FaceNet model [7], will be used. Since we lack labeled data, we can't generate triplets directly as in [7]. Instead, a 'Tinder-like' application has been developped and used by the whole company to build our 'labeled' triplets database.

To summarize, the pipeline comprises the two main following steps :

1. **Triplets collection** : Offline 'unlabeled' triplets are generated. Triplets are then labeled by the users of the app and stored in the database.
2. **Model training** : An encoding model is trained on the labeled triplets. The model is then used to compute the similarity between two 3D models.

Chapitre 2

Related work

2.1 3D Understanding

3D data can be presented in various formats, and the selection of the format is critical and depends on the specific needs of the application. A CAD model is a 3D representation of a physical object. At a higher level, the Standard for the Exchange of Product model data (STEP format) is a widely adopted ISO standard for data exchange that can represent 3D objects in CAD and related information. In this format, a CAD model is defined by its topological components such as faces, edges, or vertices and the connections between them. At a lower level, the STL format is a file format that represents 3D objects as a collection of triangles (mesh). This format is commonly used in 3D printing and computer graphics. Additionally, the point cloud format consists of a set of points in a 3D space, with each point representing a single point on the surface of the object. This format can be easily derived from an STL file by sampling points on the mesh surface. Other formats worth mentioning include voxel and multi-view image formats [13].

The decision was made to explore both STL and point cloud formats. The choice of the STL format is driven by its widespread use in the industry and the ease of generating a point cloud from it. Notably, models based on the STEP format [5], while promising, were not considered because they limit the scope too much.

Following recent trends in the field, two main classes of models were investigated, graph-based models and transformer-based models.

Graph-based models

Graph neural networks (GNN) have been used recently in numerous applications [11, 3] The flexible nature of a graph permits its usage from data sets concerning large social networks to smaller networks that describe the chemical bonds of a molecule. Graph neural networks use the correspondences between elements instead of focusing on individual elements. These correspondences help create neighborhoods and local regions, which greatly enhance the predictive accuracy of the resulting features.

Given an input mesh, a natural candidate is a graph which nodes are the vertices of the mesh and where each vertex is connected to the vertices that share a face with it. This information is not available for the different GNNs that have been developed for 3D point cloud data [9, 10, 1]. These models are designed to work with point clouds. The main challenge is to define a graph structure that captures the local and global features of the point cloud. The most common approach is to define a graph where each point is a node and the edges are defined by the k-nearest neighbors of each point. The graph is then fed to a GNN to extract features from the point cloud.

Transformer-based models

Transformers [8] and self-attention models have revolutionized machine translation and natural language processing. They can equal or even surpass convolutional networks when applied to sequences and 2D images [2].

Self-attention is especially relevant in our context, as it naturally functions as a set operator, where positional information is treated as an attribute of elements within a set. Given that 3D point clouds consist of sets of points with positional attributes, the self-attention mechanism appears particularly well-suited to handling this type of data. Many recent works have explored the application of transformers to 3D data [14, 12, 4].

2.2 Contrastive learning

Chapitre 3

Un chapitre

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3.1 Analyse aux limites

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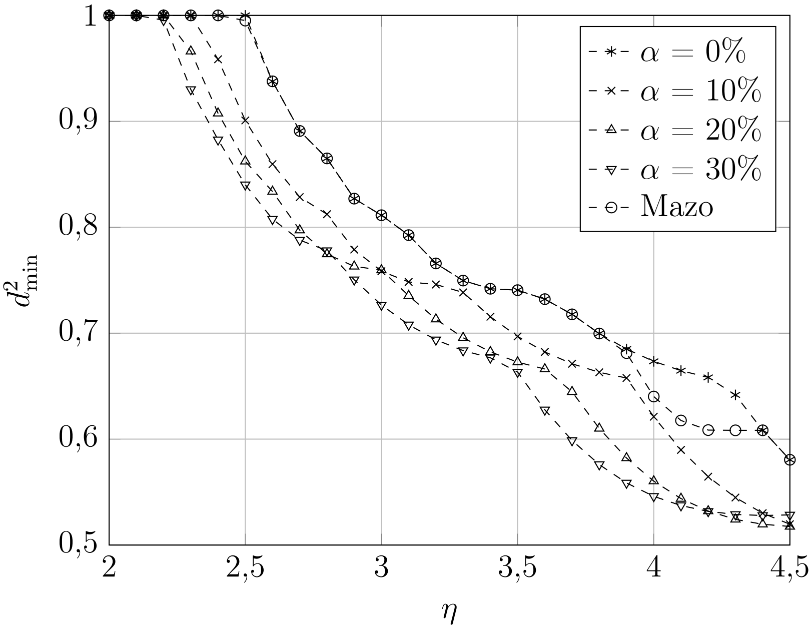

FIGURE 3.1 – Exemple de courbe TikZ.

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3.1.1 Quelques détails sur cette méthode

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3.1.2 On n'est jamais très fort pour ce calcul

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$$\begin{aligned} H_{m,n,p,q} &= \langle \check{g}_{p,q}, \mathrm{H} g_{m,n} \rangle && (3.1) \\ &= \iint\limits_{\mathbf{R}^2} S_{\mathrm{H}}(f,\tau) \, \langle \check{g}_{p,q}, \mathrm{U}_{f,\tau} g_{m,n} \rangle \, \mathrm{d}f \, \mathrm{d}\tau. && (3.2) \end{aligned}$$

3.2 Vérification par simulation numérique

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Conclusion

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Chapitre 4

Applications and perspectives

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