MSc Thesis Project Plan

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Start date:	01-09-2021
End date:	01-03-2022
External supervisor:	Guido de Jong Email: guido.dejong@radboudumc.nl
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(Preliminary) project title:	Three dimensional landmark detection in 3D CT-Scans and 3D Photos
Study program:	Computing Science (Data Science)

1 Problem Statement

Three-dimensional (3D) landmarks are used in various fields of medicine e.g. for alignment of 3D radiological images, 3D scans or 3D photos. The department of Oral and Maxilofacial Surgery at Radboudumc needs to place 3D landmarks for surgical planning, follow-up and diagnostics. Placing 3D landmarks manually is a tedious process with a high degree of inter- and intraobserver variability. Automatic landmark detection can ensure consistent and precise landmark placement. However, there are several challenges for computer-assisted approaches such as variation in device/data source, pre-processing or sampling resolution.

The Radboudumc 3D lab has 3D CT-scans and 3D photos of the face and cranium in following modalities: bony-tissue CT-scans, soft-tissue CT-scans, soft-tissue 3D photos and soft-tissue textured 3D photos. Per modality a set of 12 to 36 clinically relevant landmarks have to be detected.

2 Approach

With the recent successes and the emerging field of artificial intelligence (AI) within 3D technology the goal is to develop a neural network that automatically places landmarks in 3D photos and CT-scans of faces or craniums. The final approach either fully or partly relies on AI. We try to outperform manual and

other non-deep learning 3D landmark detection approaches in accuracy and time.

A deep learning approach in combination with one of the four modalities will be chosen. Depending on the chosen modality, up to several hundreds of partly annotated samples will be used to train the neural network. Data augmentation can be used to increase the size of training set.

Computing clusters are provided by Radboudumc efficient experimenting and training of the deep learning model.

3 Literature

There is little to no literature about 3D deep learning for the application of facial landmark detection that operates directly on the 3D data source (mesh data). Instead, we rely on literature that describe 3D deep learning in more general terms or for applications that are similar to ours [Guo et al., 2020], [Bello et al., 2020].

3D deep learning is an emerging field, but still lacks behind 2D computer vision. This because techniques such as convolution, that Convolutional Neural Networks (CNNs) rely on are not directly transferable to 3D due to the unstructuredness and irregularities in the data. Promising approaches are PointNet [Qi et al., 2017a] that use Point Clouds and take into account the permutation invariance of points in the input. Variations of PointNet are PointNet++ [Qi et al., 2017b] that manage to improve classification and segmentation performance by modelling local regions through sampling and grouping or PointCNN [Li et al., 2018] that take into account the correlation between points in the local regions. An approach that operates directly on triangular mesh data is MeshCNN [Hanocka et al., 2019], where convolutions are applied on edges and the four edges of their incident triangles, and pooling is applied via an edge collapse operation.

4 Plan

The following is a rough outline of the planning of my 6-months internship. The first month will be mainly literature research. I will read into 3D deep learning, which approaches exist and work well on similar applications. Moreover, I try to get familiar with computer graphics terminology and polygonal mesh processing including the mesh processing software MeshLab. Afterwards, I will experiment with the Headspace dataset which is available for University-based non-commercial research. When I found a deep learning for a given modality, I apply my method on the data given from Radboudumc. The last months will be dedicated to the final thesis.

There are weekly meetings in addition to spontaneous exchange in my everyday work with my external supervisor, Research coordinator of the 3D Lab at Radboudumc. Moreover, I will meet monthly with my internal supervisor,

Professor for Data Science at Radboud University.

A git repository will be set up for version control and code distribution.

References

[Bello et al., 2020] Bello, S. A., Yu, S., Wang, C., Adam, J. M., and Li, J. (2020). Review: Deep learning on 3D point clouds.

[Guo et al., 2020] Guo, Y., Wang, H., Hu, Q., Liu, H., Liu, L., and Bennamoun, M. (2020). Deep Learning for 3D Point Clouds: A Survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

[Hanocka et al., 2019] Hanocka, R., Hertz, A., Fish, N., Giryes, R., Fleishman, S., and Cohen-Or, D. (2019). MeshCNN. *ACM Transactions on Graphics*.

[Li et al., 2018] Li, Y., Bu, R., Sun, M., Wu, W., Di, X., and Chen, B. (2018). PointCNN: Convolution on X-transformed points. In *Advances in Neural Information Processing Systems*.

[Qi et al., 2017a] Qi, C. R., Su, H., Mo, K., and Guibas, L. J. (2017a). PointNet: Deep learning on point sets for 3D classification and segmentation. In *Proceedings - 30th IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2017*.

[Qi et al., 2017b] Qi, C. R., Yi, L., Su, H., and Guibas, L. J. (2017b). PointNet++: Deep hierarchical feature learning on point sets in a metric space. In *Advances in Neural Information Processing Systems*.