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PhD Thesis report:

Kacper Kania – Controllability of radiance fields with sparse information

The dissertation of Kacper Kania is focused on being able to control different aspects of neural radiance fields (NeRFs) and Gaussian splatting (GS) representations. Specifically, it aims to control facial expressions for NeRF representations of faces. Further it also aims to control lighting and level of detail for Gaussian splatting representations. The thesis consists of six chapters, including four technical chapters containing the thesis' research contributions.

The first chapter contains the introduction to the dissertation, including motivation and challenges. Further is also briefly describes the research objectives and outlines the contributions.

Chapter two introduces controllable neural radiance fields (CoNeRF). To enable control the method relies on some sparse annotations that are then propagated to the rest of the image data. It principally allows to decouple different expression changes that are seen jointly in images such that a rich controllable model can be obtained from much less data than would otherwise be required. This work was published at the IEEE/CVF International Conference on Computer Vision and Pattern Recognition (CVPR) in 2022, which is a top conference in the field.

Chapter three continues along the same lines of creating 3D representations of faces that can render novel expressions, but now focuses more on expression-dependent details such as wrinkles. These details can potentially be smaller than the resolution of the tetrahedra used to represent the face model. The proposed method BlendFields builds on Flame and VolTeMorph, but is shown to outperform prior art. This work was published at CVPR 2023.

The fourth chapter focuses on a different problem and switches from NeRFs to Gaussian Splatting. This more traditional graphics representation borrowed the volumetric rendering and gradient descent-based optimization approach from NeRF, but allows for much more efficient real-time rendering making it more popular. However, Gaussian Splatting, like NeRFs, normally don't handle variations in illumination in the images used to fit the appearance model. The contribution of this chapter, LumiGauss, aims to enable reconstruction from photo collections captured in the wild with varying lighting. For this purpose Kacper proposes to use 2D Gaussian Splatting to enable per view reconstruction, including surface reconstruction to enable decoupling of

appearance and lighting. The method includes the ability to handle shadows. This work was published at WACV 2025, which is a good quality conference more focused on applications of computer vision.

The last technical chapter focuses on enabling level of details for Gaussian Splatting. For this purpose the GS representation is encoded in a multi-channel 2D image where Gaussians with similar properties are clustered such that downsampling this image can generate a meaningful lower resolution representation. A decoder is then used to transform the image back into a GS representation with the desired level of detail. This method is shown to be quite effective compared to other methods. While delivering similar quality, it allows to much more effectively transition between levels of details.

The sixth chapter contains the conclusion. It discusses the impact of the work and future work.

The dissertation of Kacper Kania contains multiple solid contributions to the state of the art, several of which have been published in top computer vision conferences. Overall it is well written and provides a clear description of the research contributions. In addition, during his PhD Kacper also contributes to other publications that were not included in the thesis. All in all Kacper has delivered a solid dissertation that in my opinion definitely satisfies the requirements to obtain a doctorate from the Warsaw University of Technology.

Sincerely,