3D Reconstruction of Human Faces: a Laplacian Approach

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Objectives

The reconstruction of three-dimensional meshes from a limited set of points is the central focus of this study. The project aims to reconstruct the geometry of a human face — including details such as the nose, mouth, and eyes — from a simplified representation (similar to a caricature) that uses basic curves to define the face. These curves represent what we call "robust features," a concept introduced by Ian Porteus (1994), referring to features that remain consistent when the surface deforms (IZUMIYA et al., 2015). The research proposes extracting these features from a three-dimensional mesh of a human face and using them, through the Laplacian operator, to reconstruct the original surface in 3D (SORKINE, 2006). This study is guided by several fundamental questions: Do human faces have a universal set of robust features? Is it feasible to identify and differentiate faces using only these features? And finally, would it be possible to reconstruct an entire human face based solely on data regarding its robust features? These questions will be explored to assess the applicability and limitations of the proposed methodology.

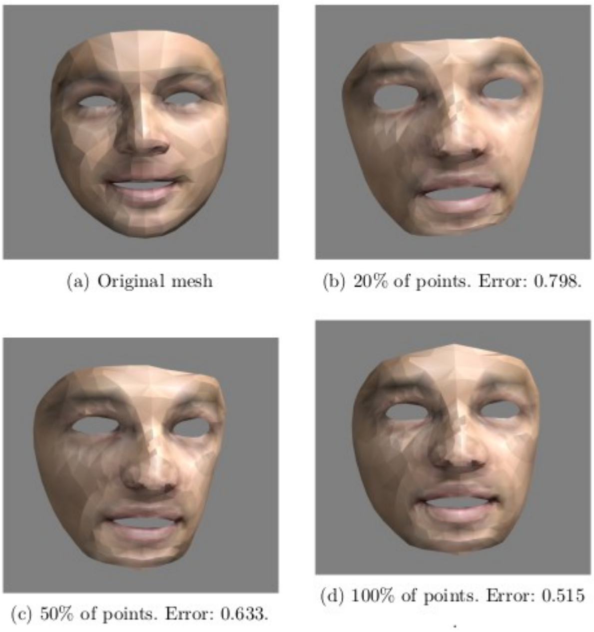
Materials and Methods

The project utilizes the MediaPipe framework for the detection and analysis of a 3D point cloud consisting of 468 points of a human face. Following the methodology developed by Danilo Marques, the project employs the extraction of robust features, including parabolic curves and *ridges* (BRUCE; GIBLIN; TARI, 1996). To achieve this, specific routines are implemented to accurately process and obtain these points, allowing for a detailed analysis of the facial structure.

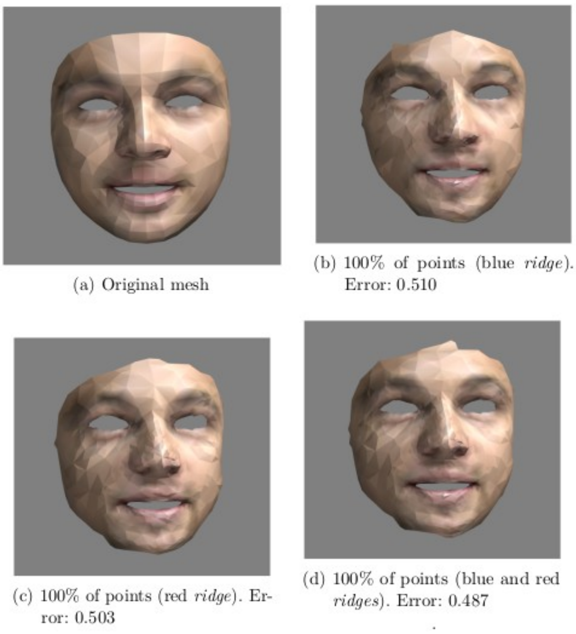
The current activities of the project include implementing MediaPipe tasks to extract the 3D point cloud of the face, followed by the identification and extraction of parabolic curves and *ridges*. Then, the Laplace-Beltrami operator is applied to reconstruct surfaces based on these key points. The reconstructed surfaces are evaluated to ensure accuracy and quality of the results. The implementation is being developed on a Linux platform, using MATLAB for most of the processing, as well as Python for the reconstruction routine.

Results

The tests were conducted by varying the number of selected anchor points (20%, 50%, and 100%), as well as the type of curve used for reconstruction (parabolic or *ridges*). The quality of the reconstruction was evaluated qualitatively, considering the fidelity of the reconstructed mesh in relation to the original mesh, and quantitatively, by measuring the error (Euclidean Distance) between the original mesh and the reconstructed mesh.



Picture 1: Reconstruction with parabolic curves.



Picture 2: Reconstruction with *ridges.*

Conclusions

The results demonstrate that the adopted approach has the potential to accurately reconstruct 3D surfaces of human faces depending on the percentage of selected points. This is evidenced by the similarity between the original mesh and the reconstructed mesh, especially as the percentage of anchor points used increases. Furthermore, it is noticeable that reconstruction using *ridges* proves to be more accurate, as the number of points is higher compared to parabolic curves.

Acknowledgements

The project is supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo), nr. 2023/15751-3, and is also part of the FAPESP thematic project nr. 2019/07316-0.

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