Computer Vision 3D Reconstruction for Prosthetic Limb Design

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Introduction

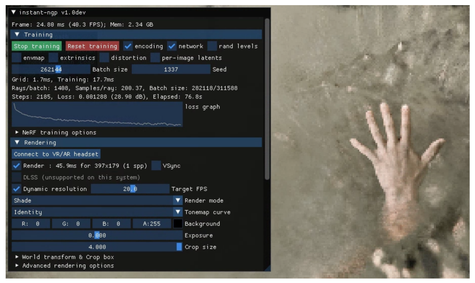
Prosthetics research and development has been largely focused on improving functionality and usability of the prosthetic for the user, however, has been lacking in accommodating the individuality of the users. The absence of diversely sized prosthetic parts may impede prosthetic users from fully considering their prosthetic a true extension of themselves.

Problem Statement

Individuals who have lost a limb require prostheses, and currently, there are approximately 1.9 million people who fall under this category in the US. Compared to traditional prosthetic design techniques, Computer Vision 3D reconstruction method is a low-cost and portable solution, capable of easy manipulation and of making captures simultaneously.

Prior Work

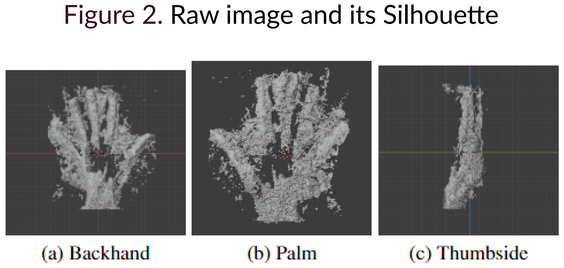
Instant NGP (Neural Graph-based Parsing) proposed a computationally efficient way to render 3D volume from a set of 2D images using NeRF. The method used in NGP 3D reconstruction, involves using a neural network to predict a graph-based representation of the 3D scene geometry from a single input image.



Methods

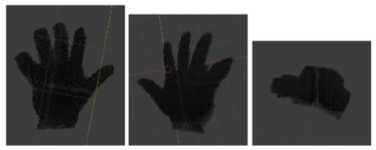
In this project, we aimed to evaluate the accuracy of NVIDIA's Instant-NGP NeRF generating network for anatomical 3D reconstruction. As a baseline for our evaluation, we utilized the space carving method which required silhouettes to be determined for each image.

Figure 2. Raw image and its Silhouette



(a) Backhand (b) Palm (c) Thumbside

Figure 3. Instant-NGP Model Views



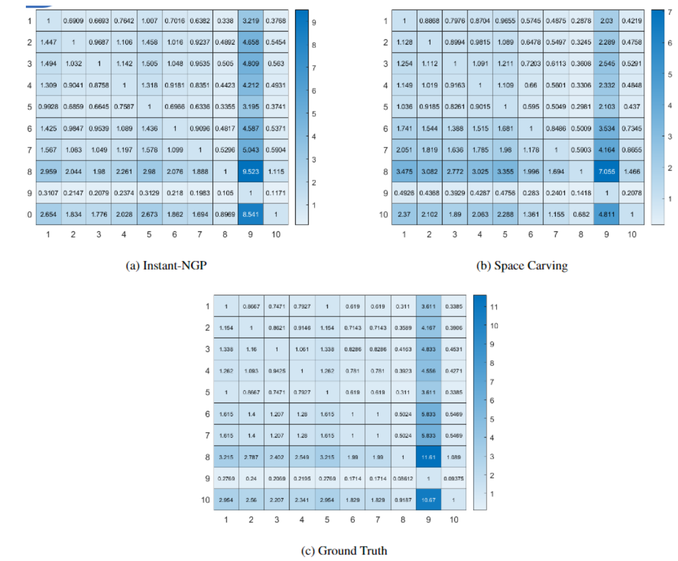
(a) Backhand (b) Palm (c) Pinkyside

Figure 4. Space Carving Model Views

Measurement

Anatomical features were measured, and the ratios between features were determined for model comparison.

Features	Ground Truth	Instant-NGP	Space Carving
Thumb	6.5	0.733	0.974
Index	7.5	1.061	1.099
Middle	8.7	1.095	1.222
Ring	8.2	0.9598	1.120
Pinky	6.5	0.7282	1.009
Palm height	10.5	1.045	1.696
Palm Width	10.5	1.149	1.999
Pinky to Thumb Separation	20.9	2.170	3.387
Finger Width (Index)	1.8	0.227	0.480
Hand Height (Thumbside)	19.2	1.946	2.310



(a) Instant-NGP (b) Space Carving

(c) Ground Truth

Figure 5. Model Ratio Matrices

Results

To evaluate the accuracy of our models, we compared each element of the model ratio matrices to the ground truth matrix. Error was calculated as follows:

$$Error = \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{x'_{i,j} - x_{i,j}}{x_{i,j}} \quad (1)$$

Model	Accuracy(%)
Space Carving	95.61
Instant-NGP	98.98

Presentation Link:
https://drive.google.com/file/d/1gzjvbutI9rC5WULtfiIARP-bAtZrjX80F/view?usp=sharing

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