Restoring Greek Sculptures
with Inpainting and 3D Reconstruction

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High Level Computer Vision
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Motivation

The idea behind this project comes from a tweet:

[1]

Motivation

- The Institute for Digital Archaeology (IDA) wants to **add colour** to **3D scanned sculptures**.

- We want to **recover broken limbs** (arms) of ancient sculptures and get **3D reconstruction without need of 3D scanning**.

British Museum facing legal action over Parthenon marbles 3D scan refusal

Institute for Digital Archaeology says it intends to serve injunction against museum imminently

[2]

Parthenon marbles at the British Museum in London. Photograph: Neil Hall/EPA

Related Work

- Master's thesis: **Restoration of Damaged Face Statues Using Deep Generative Inpainting Model.**
- We drew inspiration from it.
- Its code is **not publicly available.**


[3]

Overview

Data processing → Image inpainting → 3D reconstruction

Data processing

1. Data collection
2. Pose estimation for joints annotation
3. Arm masking
4. Segmentation

Image inpainting

Training DL architectures on our data:

- U-Net
- GAN

3D reconstruction

Inference on dust3r model for 3D reconstruction

Data processing

Collection of public datasets → Pose estimation for joints annotation → Masking and filtering

MoveNet
[9]

\+ Thresholding on arm joints

Inpainting

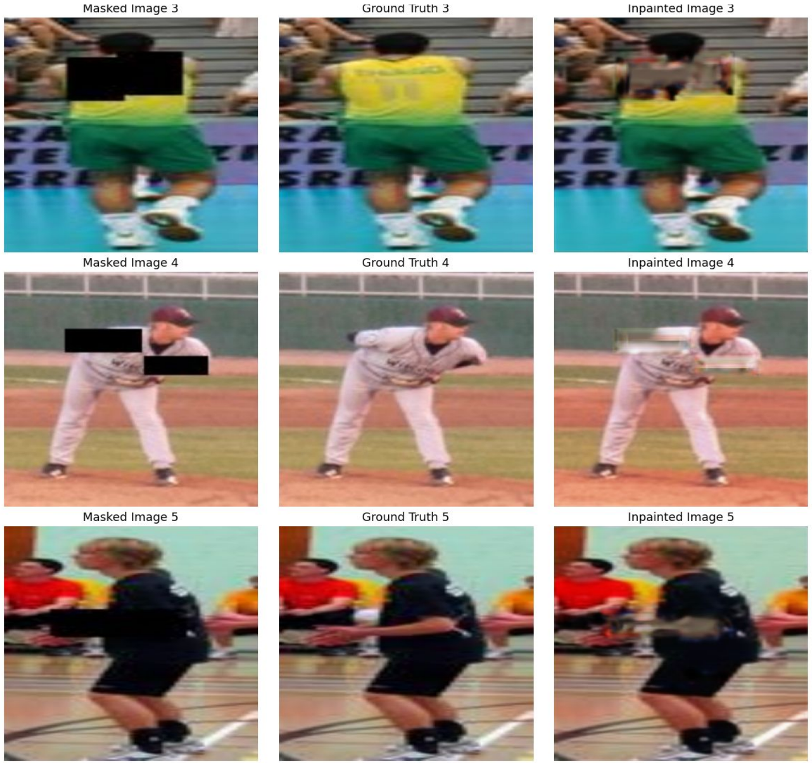
U-Net

- As a baseline.
- Blurred results.
- UNet [12]

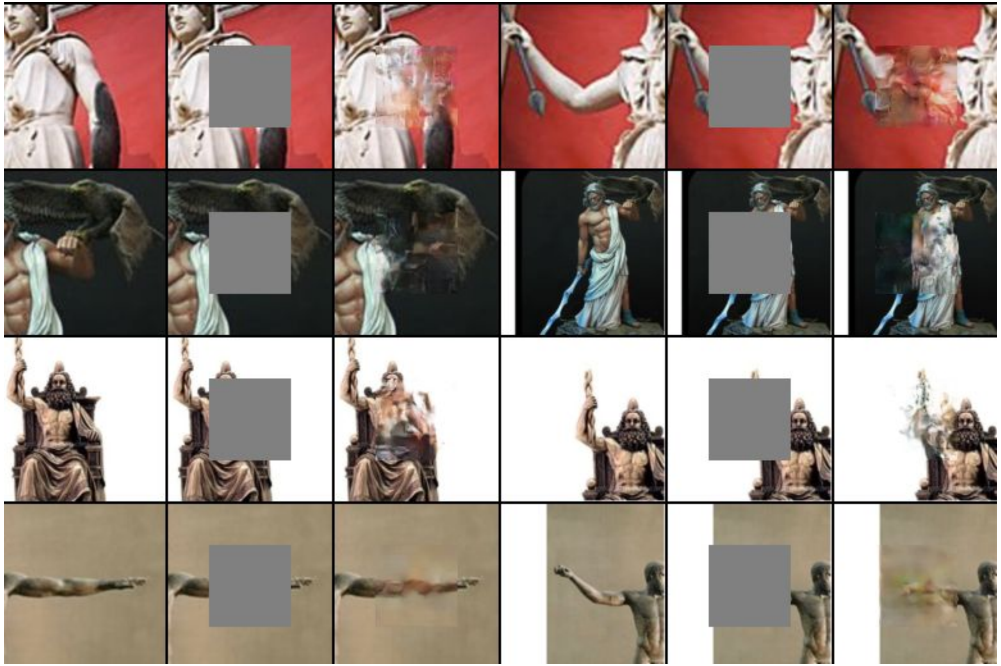
GANs

- As an improvement of the U-Net architecture.
- Context-Encoder [13]

UNET: Results



Context Encoders: Results

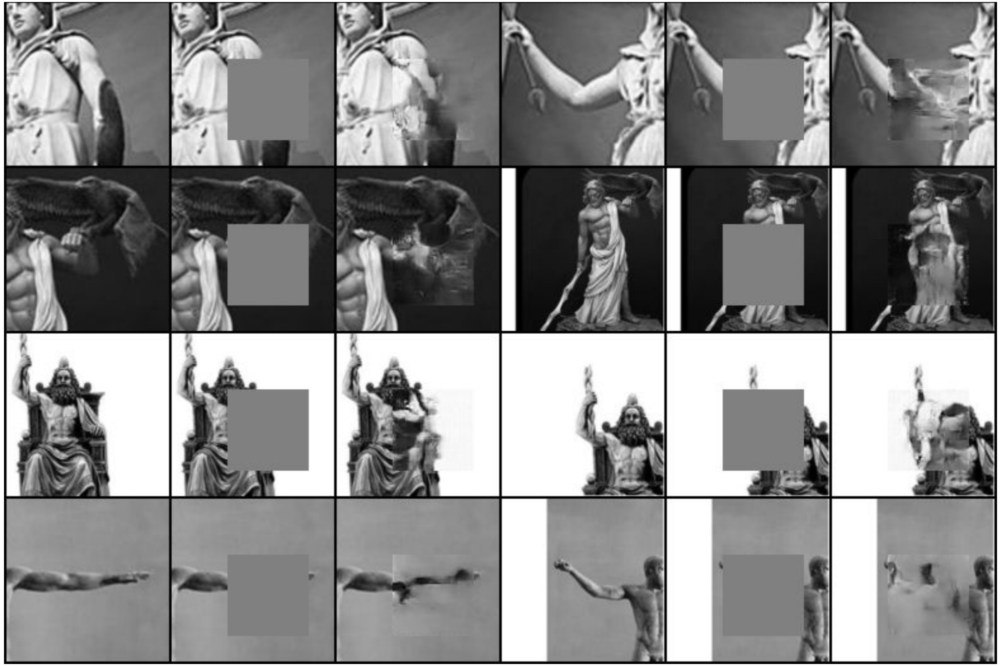


Sampling after 24999 steps. L1: 0.092373, PSNR: 17.671551, SSIM: 0.526113

Limitations with RGB Images

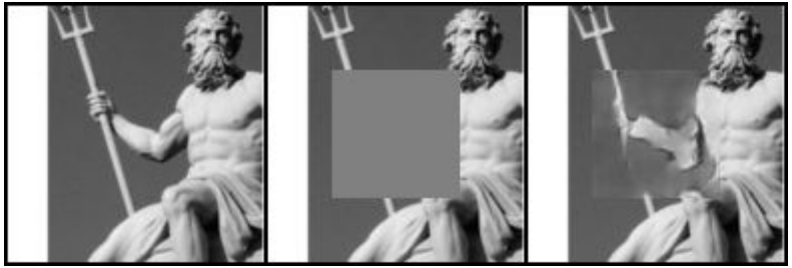
Inpainting sculptures with human skin tone.

Greyscale Images: Results



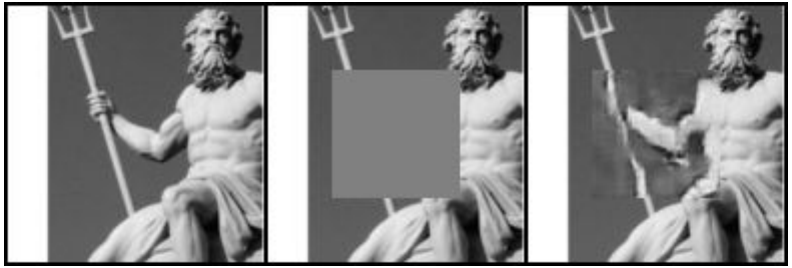
Sampling after 24999 steps. L1: 0.121197, PSNR: 15.187092, SSIM: 0.420290

Limitations with Static Mask



Results with Black and White
(static central mask)

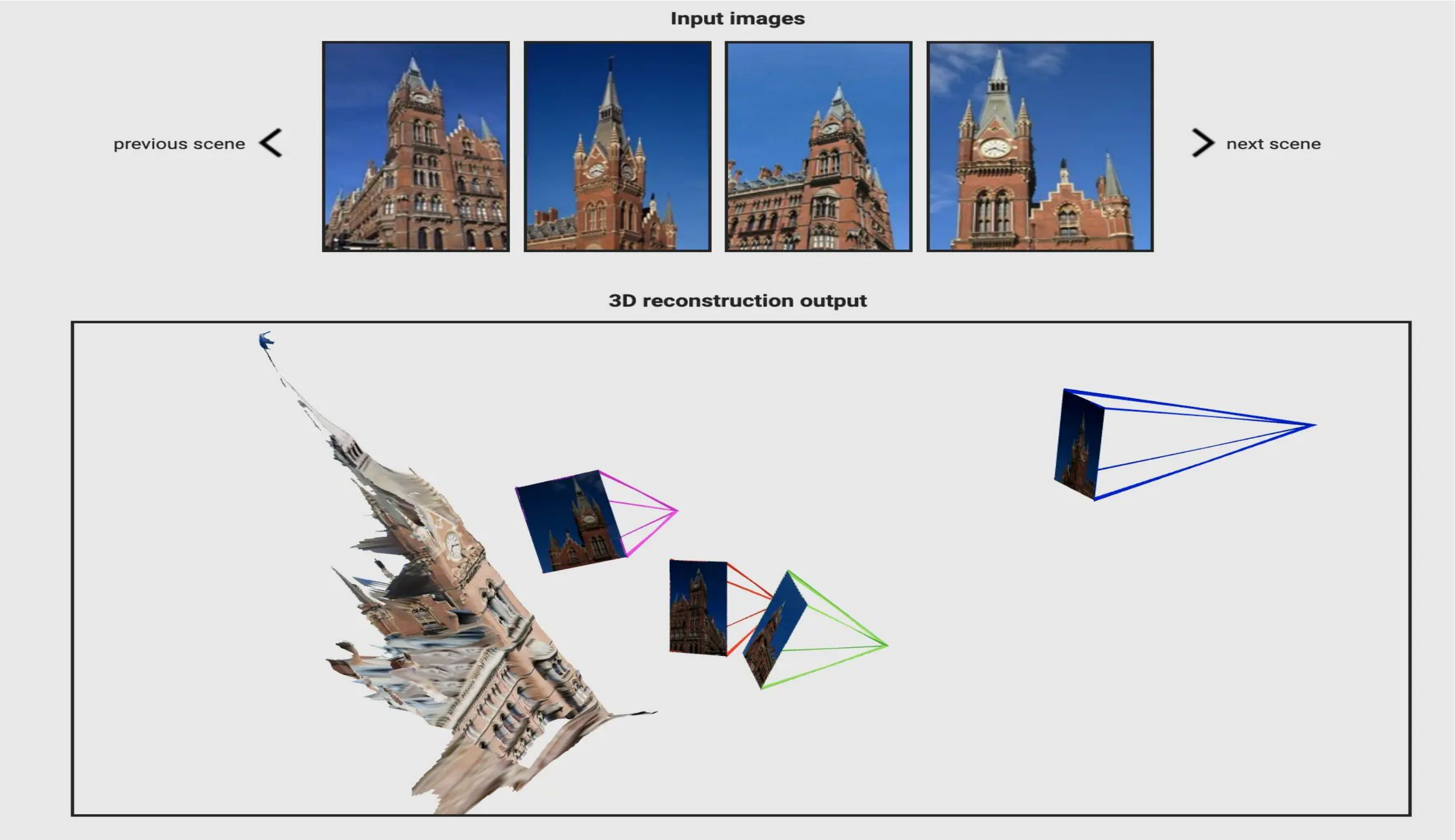
Movement of Mask: Results



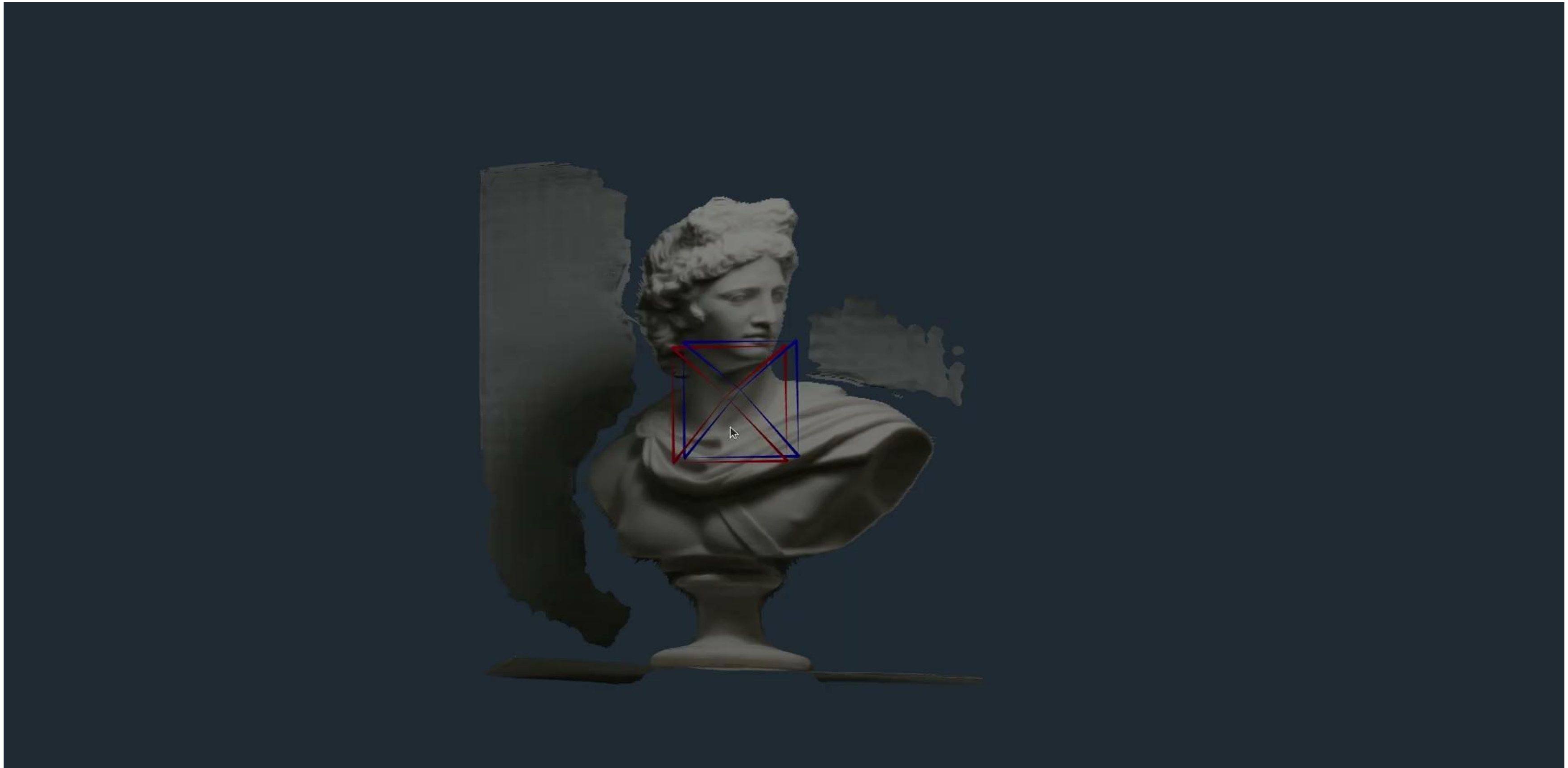
Results with Black and White
(after changing the masks movement within 30 pixel radius)

3D Reconstruction with Dust3r

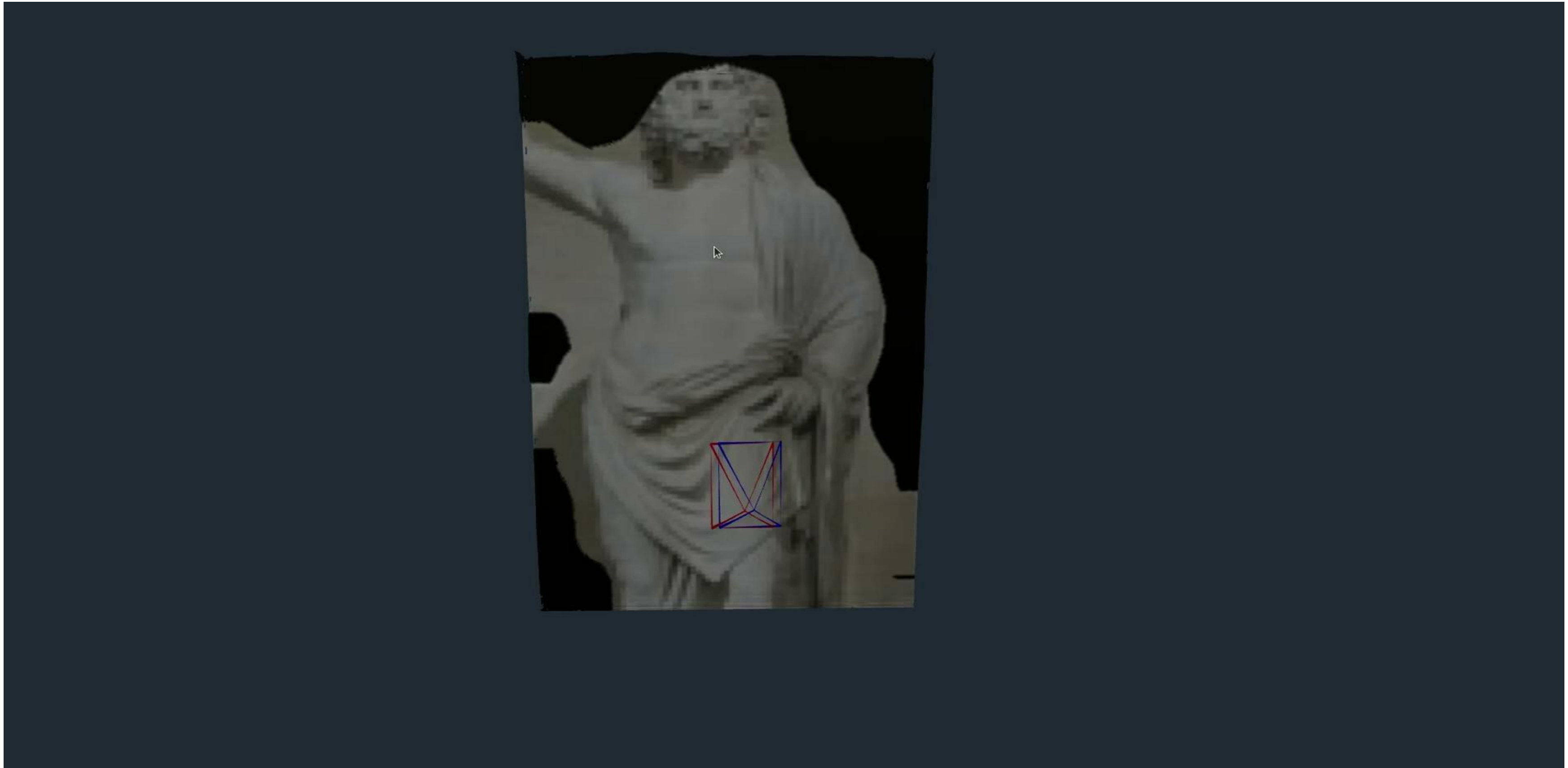
[11]



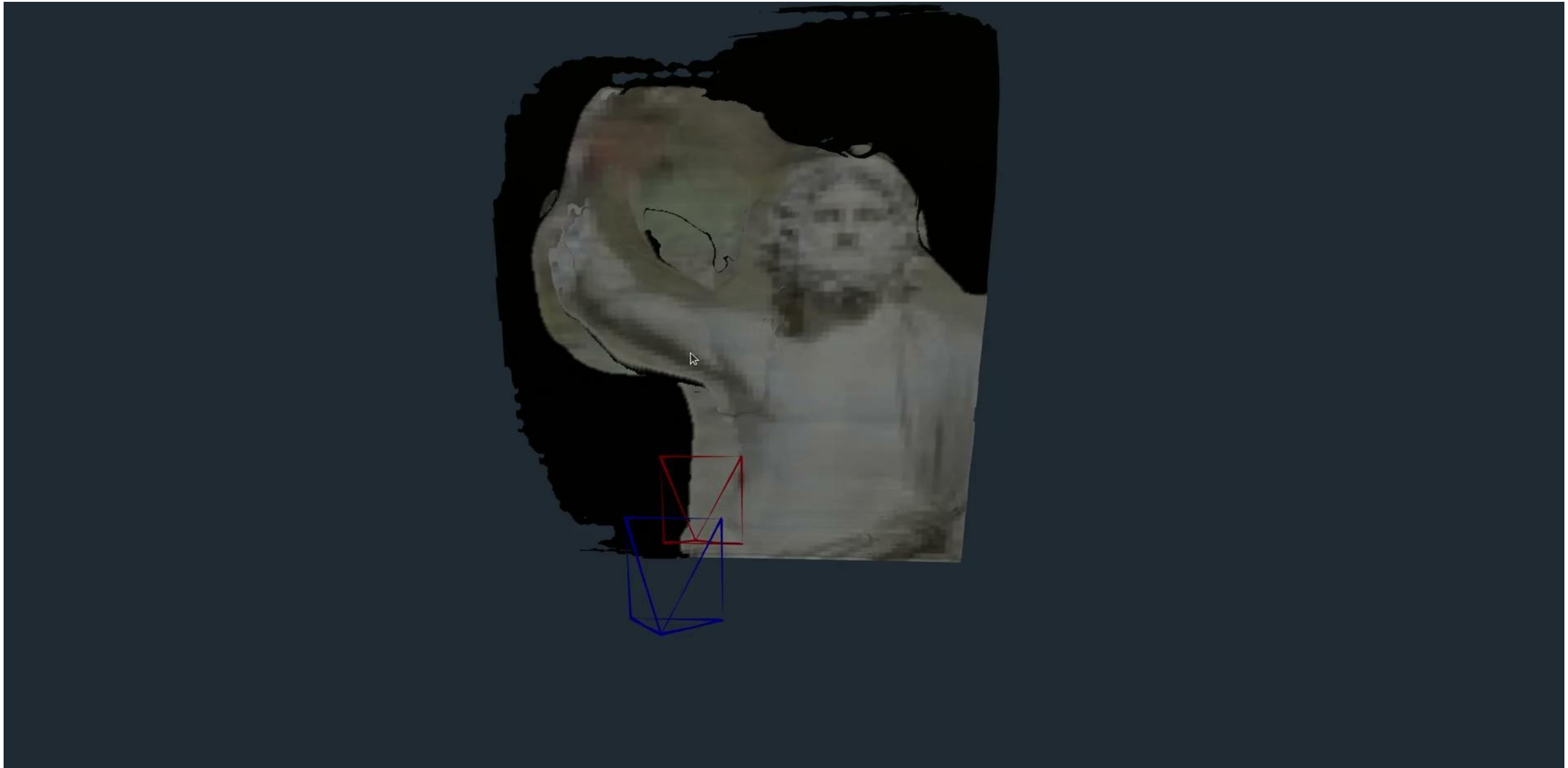
3D reconstruction on High Resolution Image



3D reconstruction on Low Resolution Image

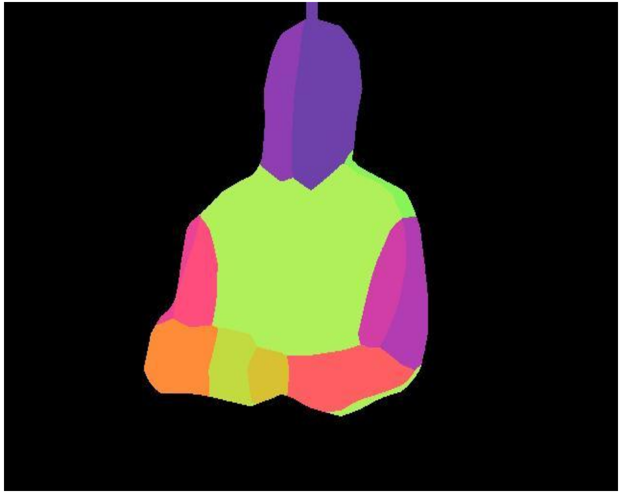
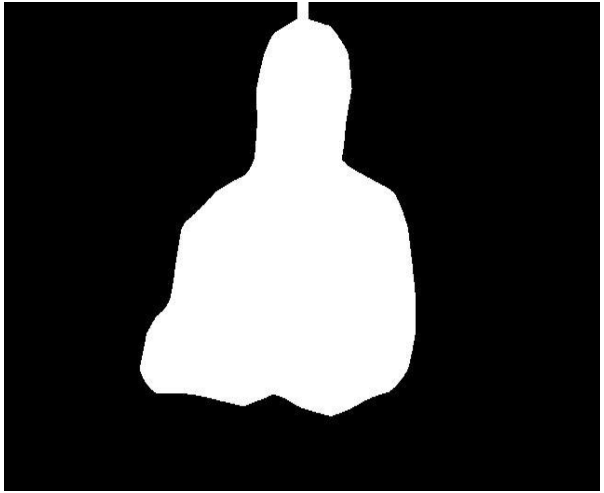


3D reconstruction on Inpainted Image



Future work

Body segmentation with BodyPix model. [10]


Future work

Body segmentation on our dataset.

Conclusions

- U-Net gives poor results compared to GAN architecture.
- Training on human data results in inpainted statues with skin tone.
- Moving the mask slightly around the center helps the model generalize.
- 3D reconstruction with dust3r gives poor results for low quality images and even worse for grayscale.

References

Motivation

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2. Brown, M. (2022). **British Museum facing legal action over Parthenon Marbles 3D scan refusal**. The Guardian. https://www.theguardian.com/artanddesign/2022/mar/29/british-museum-facing-legal-action-parthenon-marbles-3d-scan-refusal

Related work

3. Theodorus, A. (2020, August). **Restoration of damaged face statues using deep generative inpainting model.** University of Twente. http://essay.utwente.nl/82706/

Datasets

4. Johnson, S., & Everingham, M. (2010). **Leeds Sports Pose Dataset**. Retrieved from https://paperswithcode.com/dataset/lsp
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Code and models

9. TensorFlow. (n.d.). **MoveNet: Ultra fast and accurate pose detection model.** Retrieved from https://www.tensorflow.org/hub/tutorials/movenet
10. De-code. (2024). **Python-TF-BodyPix**. GitHub. https://github.com/de-code/python-tf-bodypix
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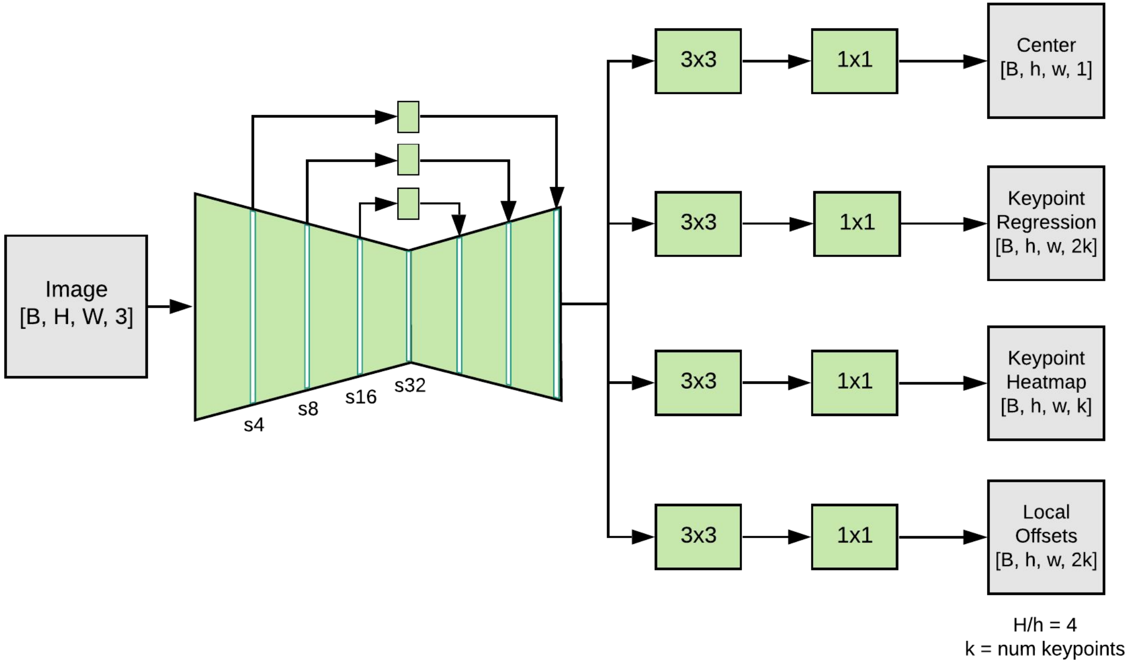
12. JASON. (2024). **Context Encoder PyTorch. GitHub.** https://github.com/xyfJASON/context-encoder-pytorch
13. Ronneberger, O., Fischer, P., & Brox, T. (2015). **U-Net: Convolutional Networks for Biomedical Image Segmentation.** CoRR. http://arxiv.org/abs/1505.04597

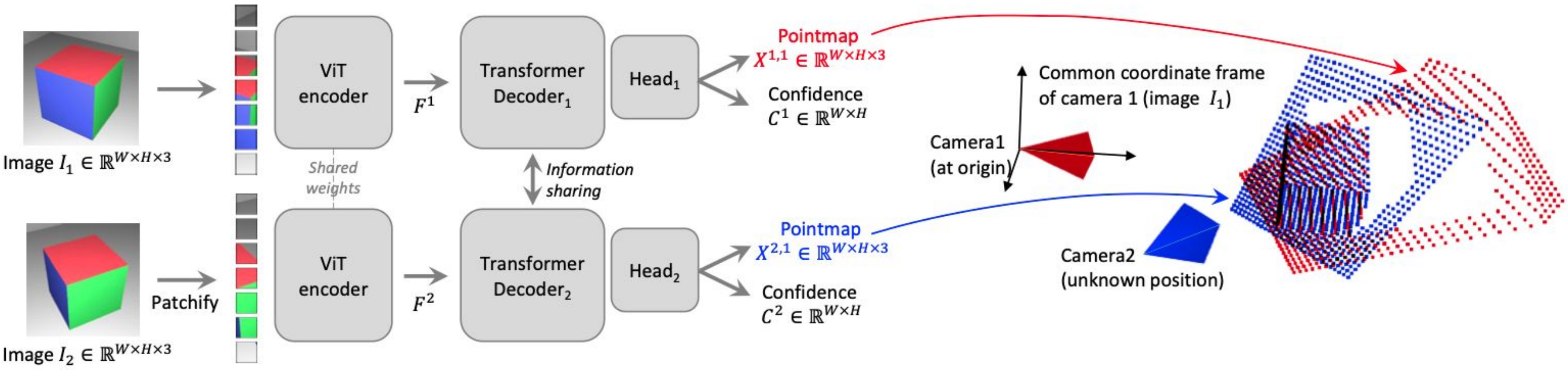
Questions

MoveNet Architecture



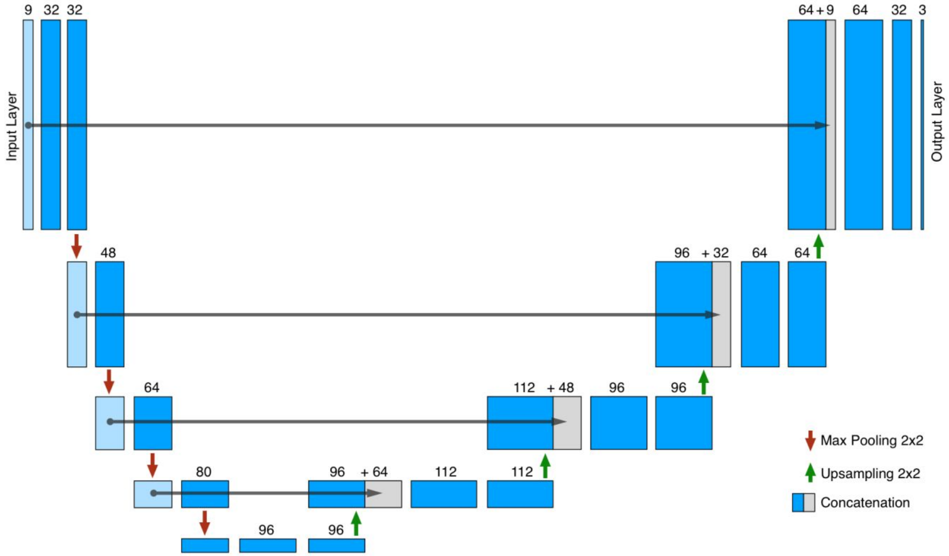
TensorFlow. (n.d.). MoveNet: Ultra fast and accurate pose detection model. Retrieved from https://blog.tensorflow.org/2021/05/next-generation-pose-detection-with-movenet-and-tensorflowjs.html

Dust3r Architecture

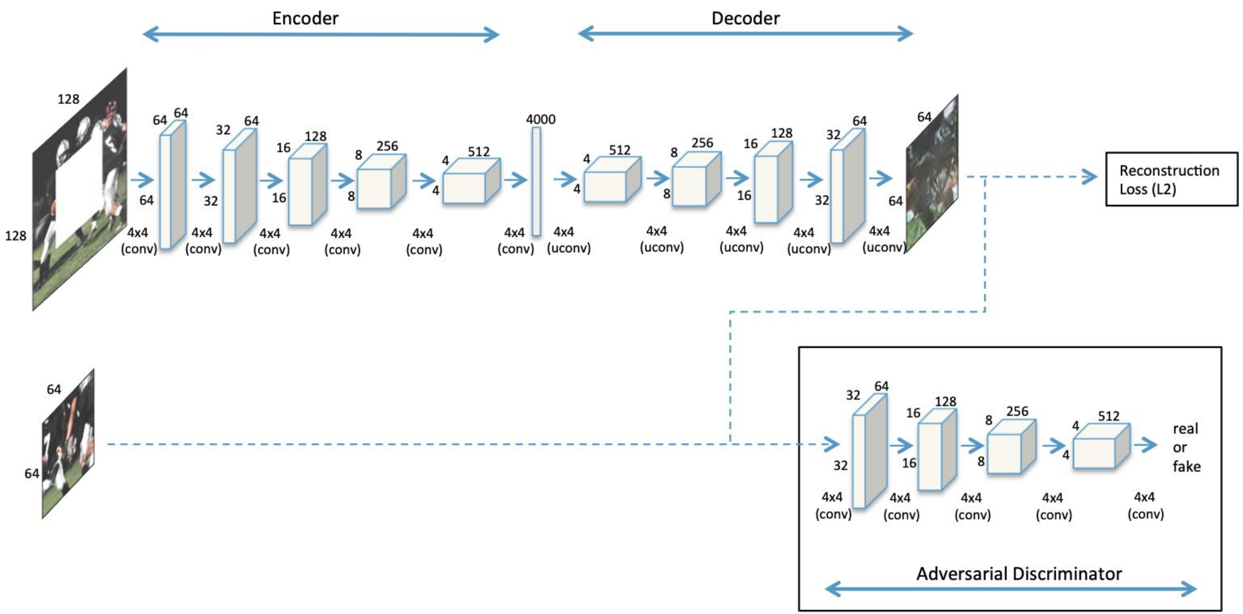


Wang, S., Leroy, V., Cabon, Y., Chidlovskii, B., & Revaud, J. (2023). **DUSt3R: Geometric 3D Vision Made Easy**. arXiv. https://arxiv.org/abs/2312.14132

U-Net Architecture

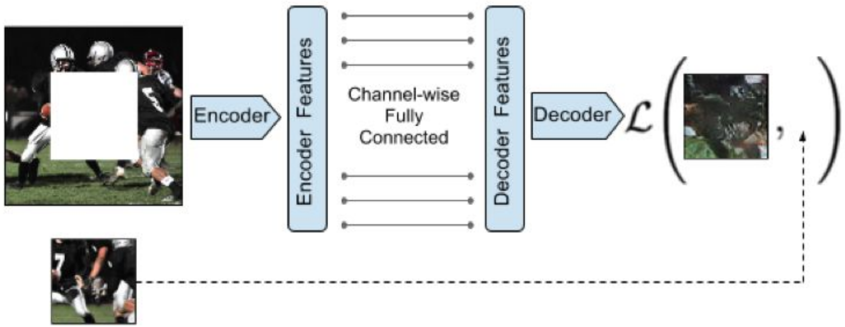


GANs Architecture



Pathak, D., Krähenbühl, P., Donahue, J., Darrell, T., & Efros, A. A. (2016). Context Encoders: Feature Learning by Inpainting. CoRR, abs/1604.07379. http://arxiv.org/abs/1604.07379

GANs Architecture



Pathak, D., Krähenbühl, P., Donahue, J., Darrell, T., & Efros, A. A. (2016). Context Encoders: Feature Learning by Inpainting. CoRR, abs/1604.07379. http://arxiv.org/abs/1604.07379

Metrics and Losses

Grayscale:
[Train] step: 24999, loss_adv_D: 0.033320, lr_D: 0.000200
[Train] step: 24999, loss_rec: 0.041915, loss_adv_G: 6.895699, lr_G: 0.002000
[Eval] step: 24999, l1: 0.121197, psnr: 15.187092, ssim: 0.420290

RGB:
[Train] step: 24999, loss_adv_D: 0.914082, lr_D: 0.000200
[Train] step: 24999, loss_rec: 0.008003, loss_adv_G: 0.828666, lr_G: 0.002000
[Eval] step: 24999, l1: 0.092373, psnr: 17.671551, ssim: 0.526113