Chair of Computer Vision & Artificial Intelligence
Department of Informatics
Technische Universität München

Face Shape Segmentation Mask Anonymization using a Generative Adversarial Network

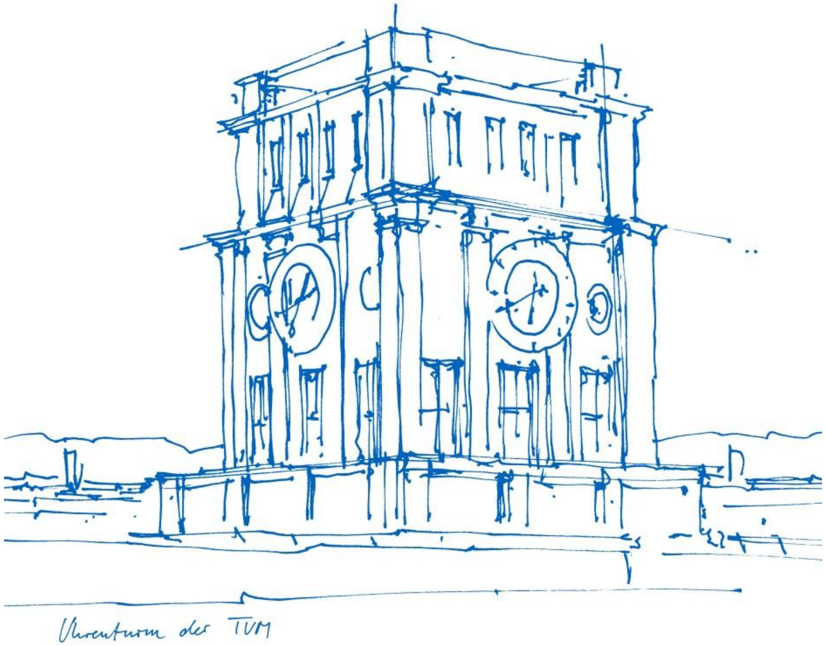
Candidate: Filippo Simonazzi

Supervisor: Maxim Maximov

Advisor: Prof. Dr. Laura Leal-Taixé

Technical University of Munich

Chair for Computer Vision and Artificial Intelligence



Introduction

Increased use of **face detection and tracking models** raises questions about **privacy.**

In most situations, it is not necessary to **identify** the subject, but it is sufficient to **detect** it.

How to perform face obfuscation?

Related Work

Face Anonymization Task

Heuristic Methods

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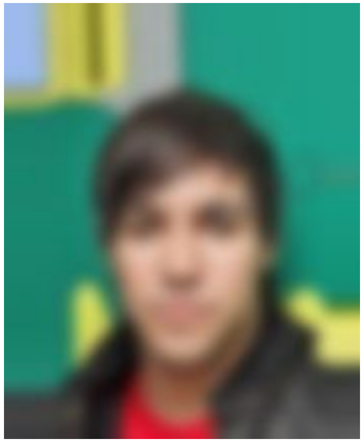
Related Work

Face Anonymization Task

Heuristic Methods

- Blurring



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Related Work

Face Anonymization Task

Heuristic Methods

- Blurring
- Pixelization

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Related Work

Face Anonymization Task

Heuristic Methods

- Blurring
- Pixelization
- Masking

Related Work

Face Anonymization Task

Heuristic Methods

- Blurring
- Pixelization
- Masking

- **Risk of identity leak**
- **Unrealistic results**

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Related Work

Face Anonymization Task

Heuristic Methods

- Blurring
- Pixelization
- Black Box

Data Driven Models

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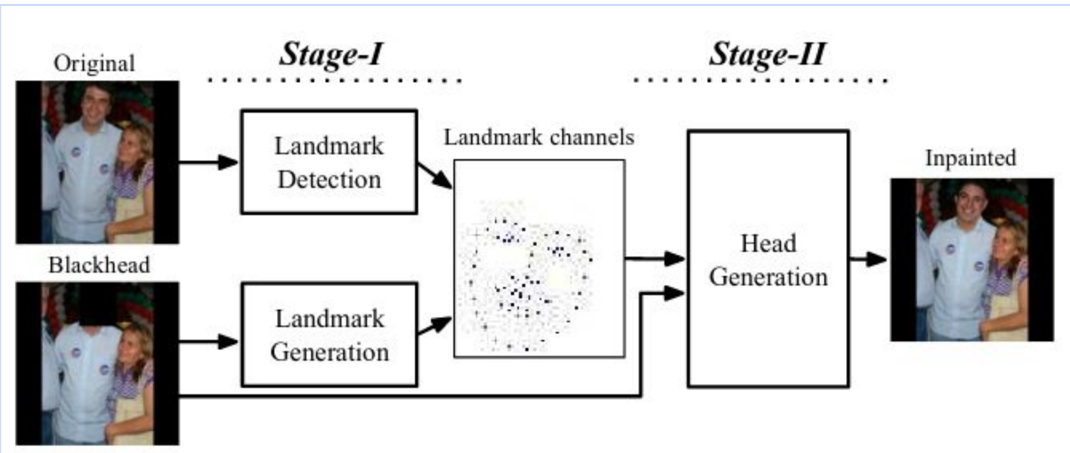
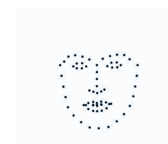
Related Work

Face Anonymization Task

Data Driven Models





Input Face Landmarks & Background

- *Natural and Effective Obfuscation by Head Inpainting*

- Facial Landmark Generation

- Head Inpainting Conditioned on Facial Landmark

Sun, Q., Ma, L., et al. 2018

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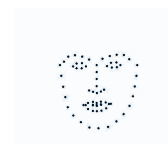
Related Work

Face Anonymization Task

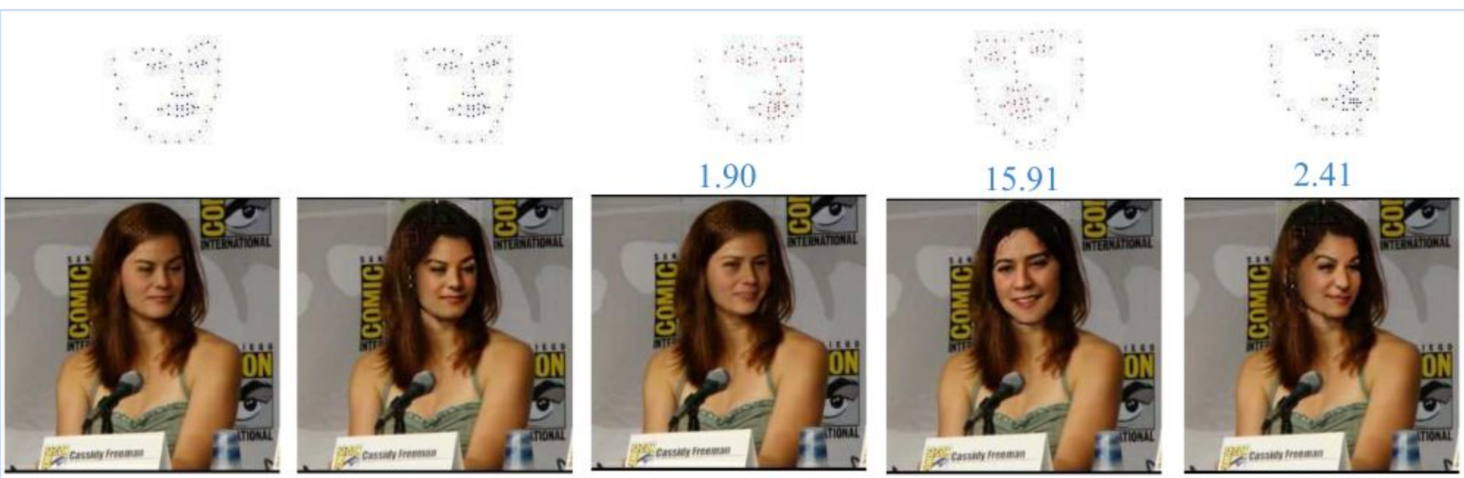
Data Driven Models

- **No control over the generated identity**
- **Generated faces may have artificial poses**
- **Computationally expensive**



Input Face Landmarks & Background

- *Natural and Effective Obfuscation by Head Inpainting*



Sun, Q., Ma, L., et al. 2018

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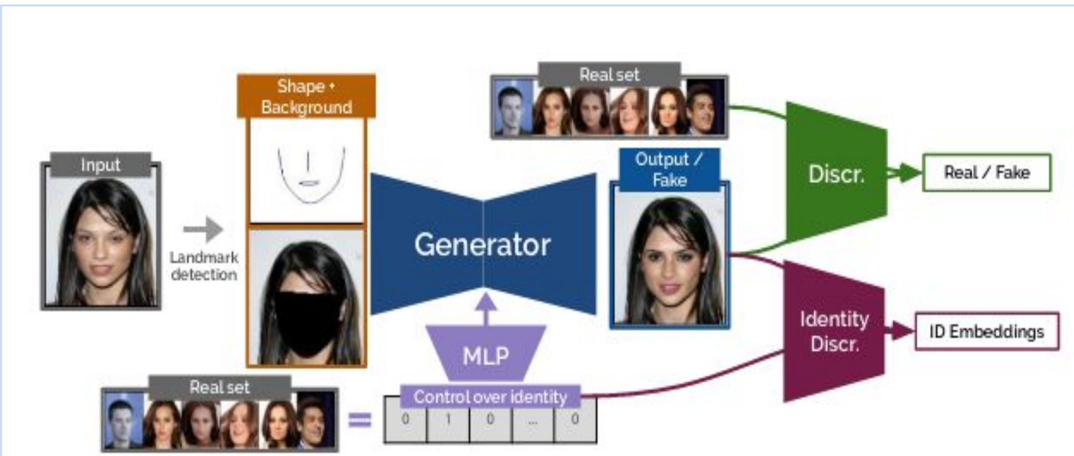
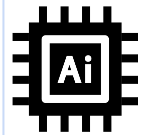
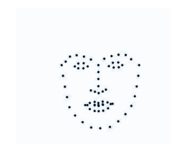
Face Anonymization Task





Data Driven Models



Input Face Landmarks & Background

- *Natural and Effective Obfuscation by Head Inpainting*
- *CIAGAN*

- Identity control on the generated output
- Little identity information given to the generator

Maximov, M., Elezi, I., Leal-Taixé, L., 2020

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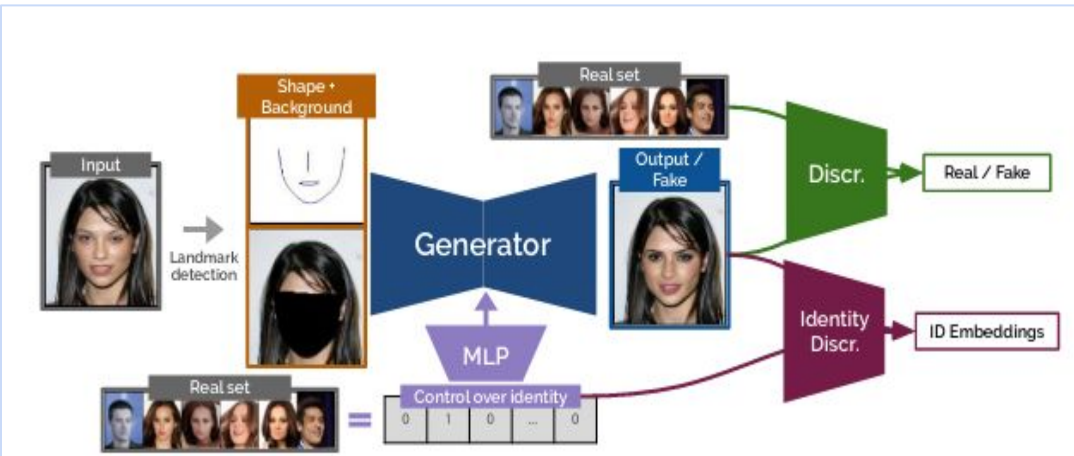
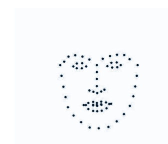
Related Work

Face Anonymization Task



Data Driven Models



Input Face Landmarks & Background

- Identity control on the generated output
- Little identity information given to the generator

- *Natural and Effective Obfuscation by Head Inpainting*
- *CIAGAN*

No option to change the shape of the original face

Maximov, M., Elezi, I., Leal-Taixé, L., 2020

Project Overview

THESIS
INVESTIGATION

Project Overview

Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

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Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

Segmentation Masks

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Project Overview

Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

THESIS INVESTIGATION

Segmentation Masks

More control over the single components of the faces

Project Overview

Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

THESIS INVESTIGATION

Segmentation Masks

Constraints on neck and hair

More control over the single components of the faces

Project Overview

Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

Segmentation Masks

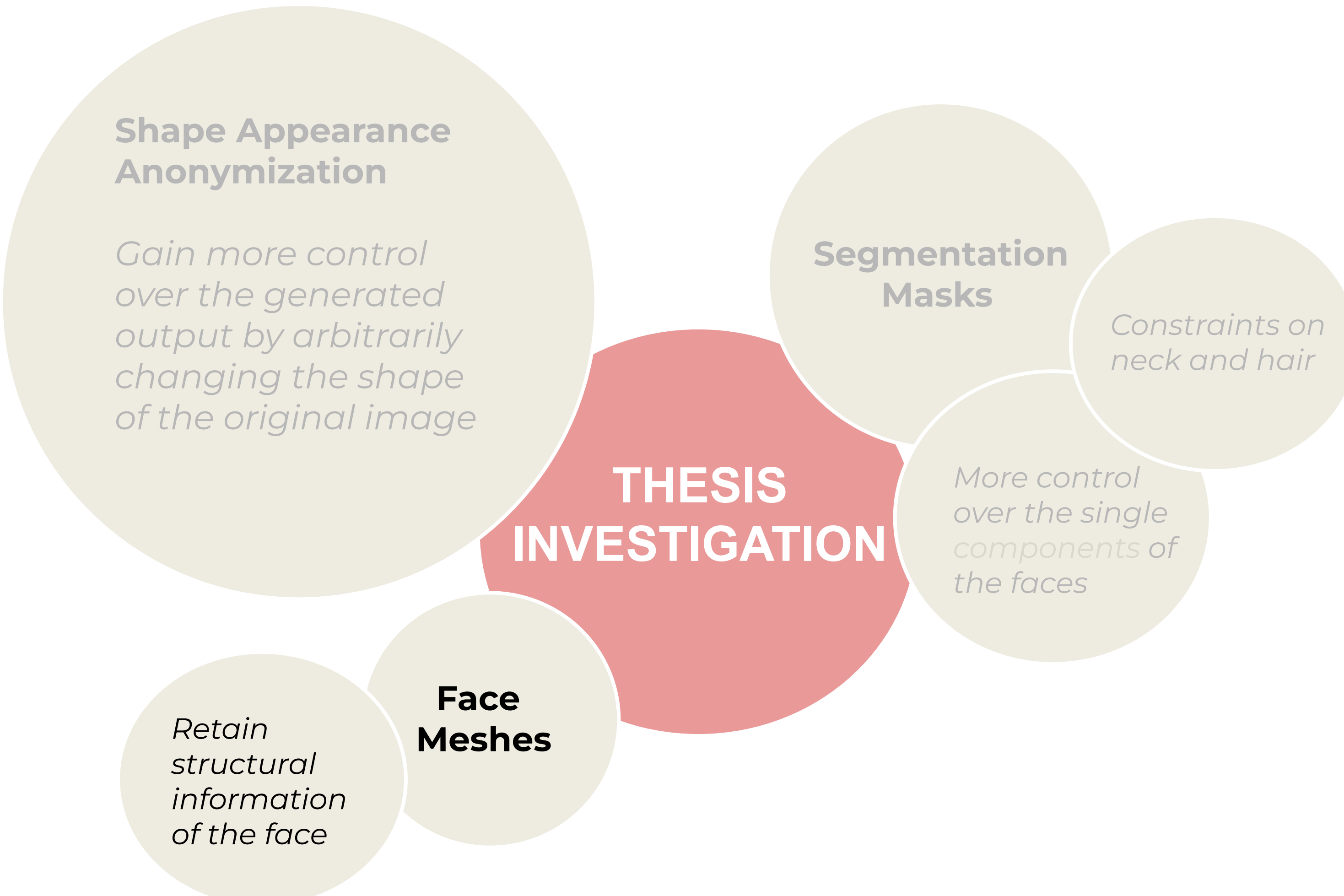
Constraints on neck and hair

More control over the single components of the faces

THESIS INVESTIGATION

Face Meshes

Project Overview



Project Overview

Shape Appearance Anonymization

Gain more control over the generated output by arbitrarily changing the shape of the original image

Segmentation Masks

Constraints on neck and hair

THESIS INVESTIGATION

More control over the single components of the faces

Face Meshes

Retain structural information of the face

The pipeline is developed building on top of CIAGAN

Project Overview

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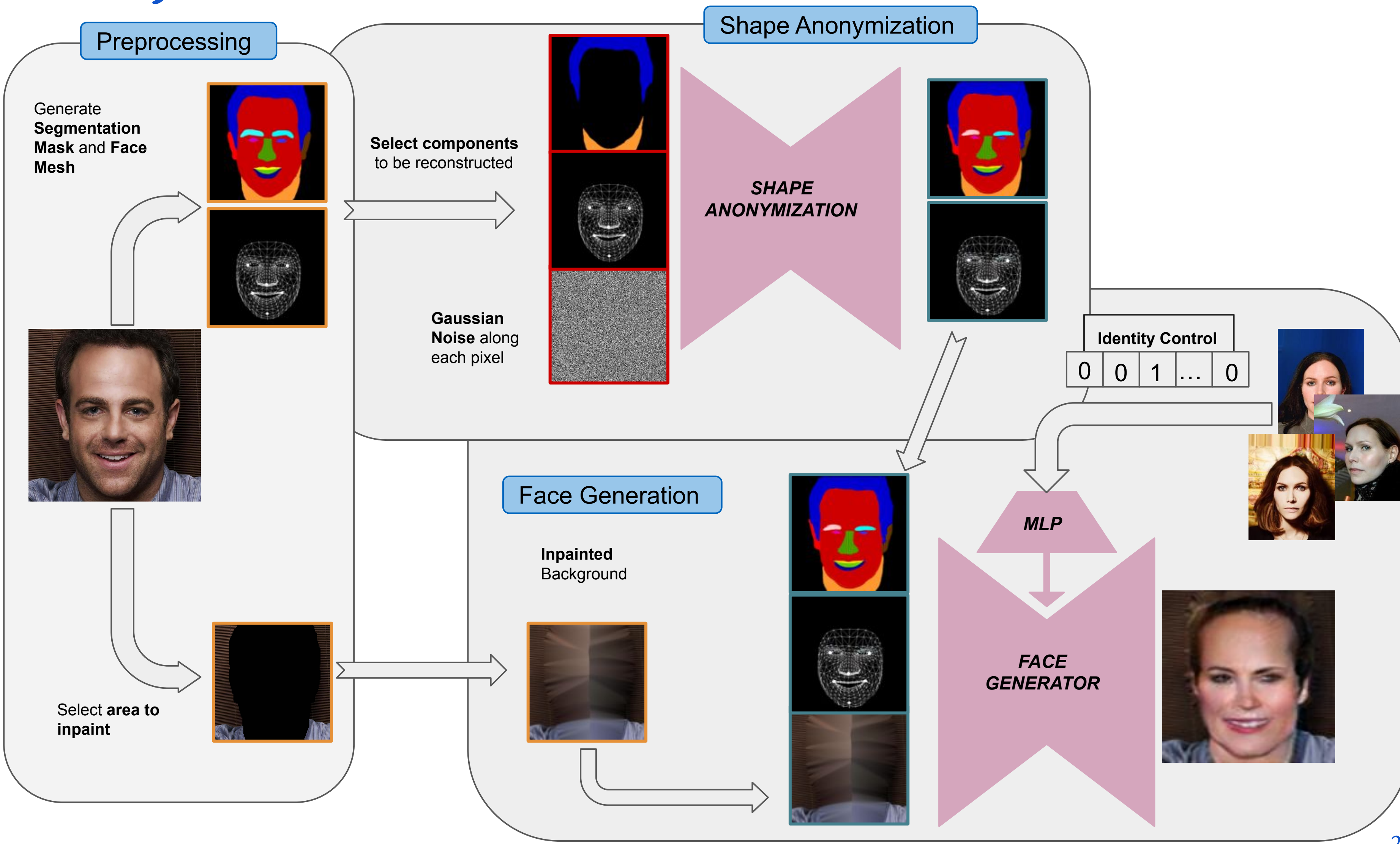
THESIS CONTRIBUTION

Full Anonymization Pipeline

- Any input size is supported
- Shape anonymization model
  - Flexible architecture
  - Ensures diversity
- Face Generator
  - Identity control as in CIAGAN
- Applicable to video frames

Project Overview



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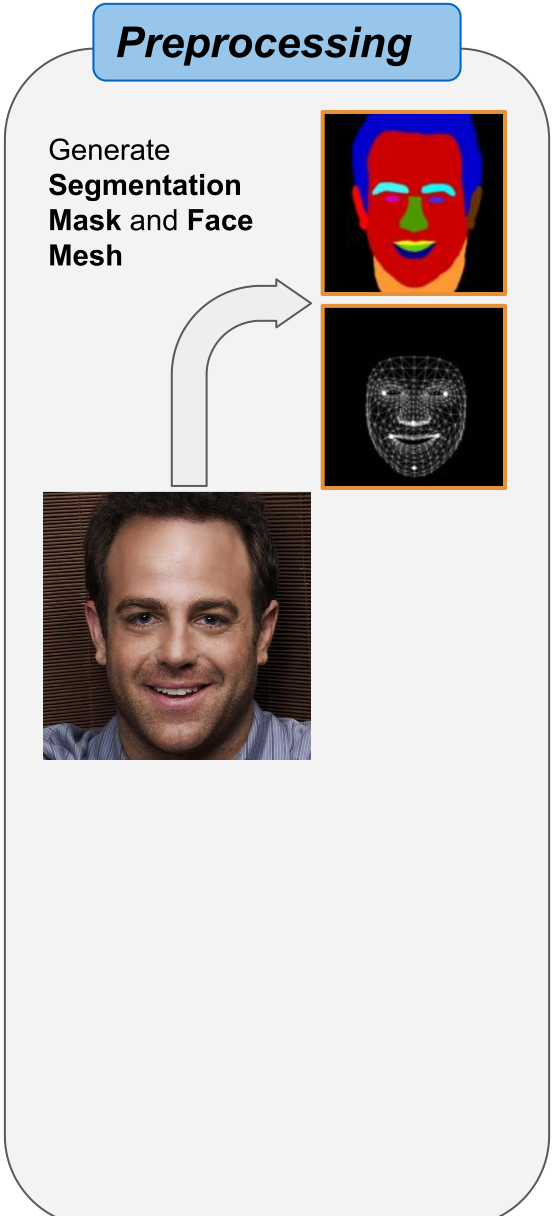
Preprocessing



- **Dlib Detector**
- **Face Parsing**
- **MediaPipe**

Lee, C. et al. 2020
Lugaresi, C. et al 2019

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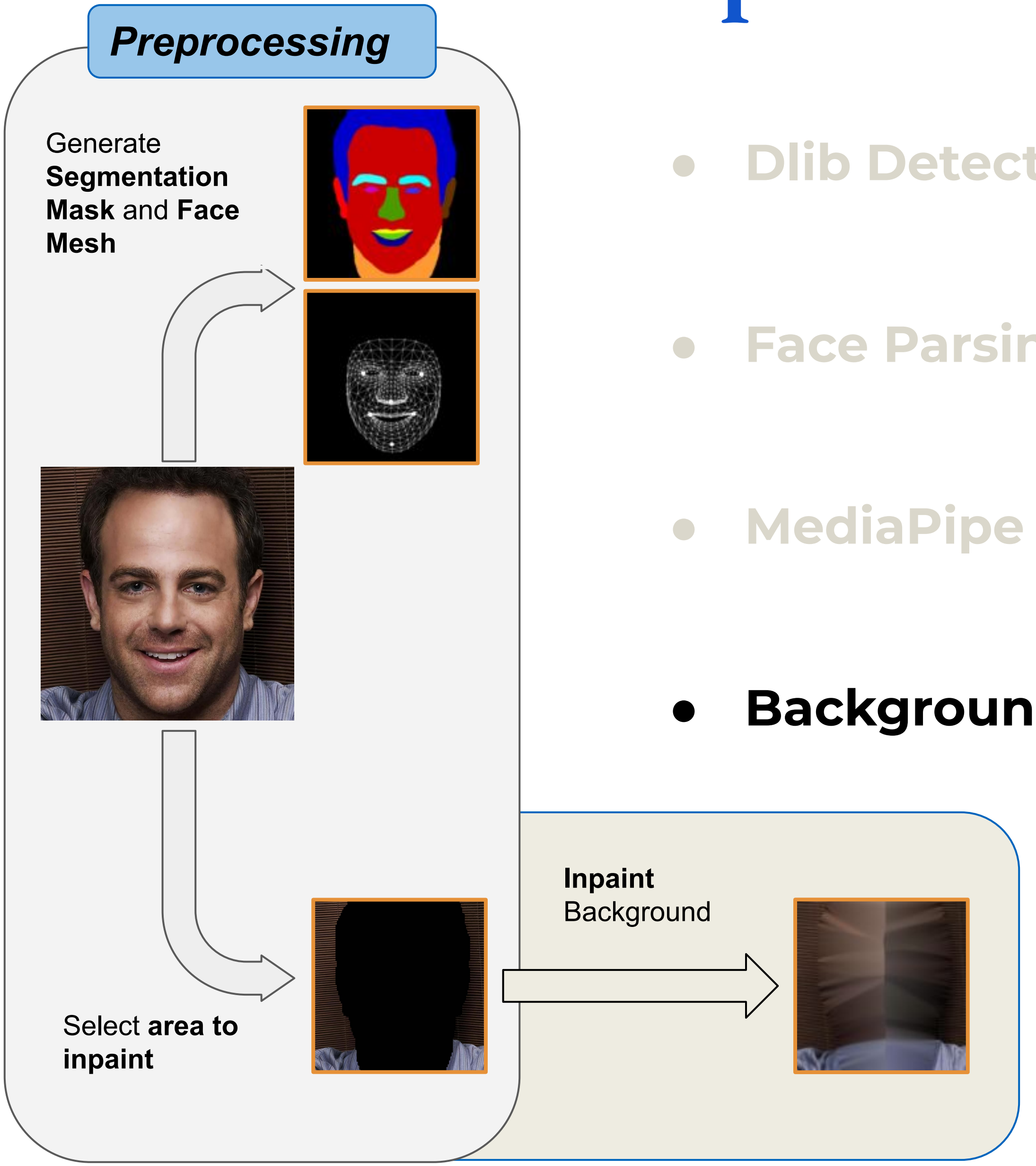
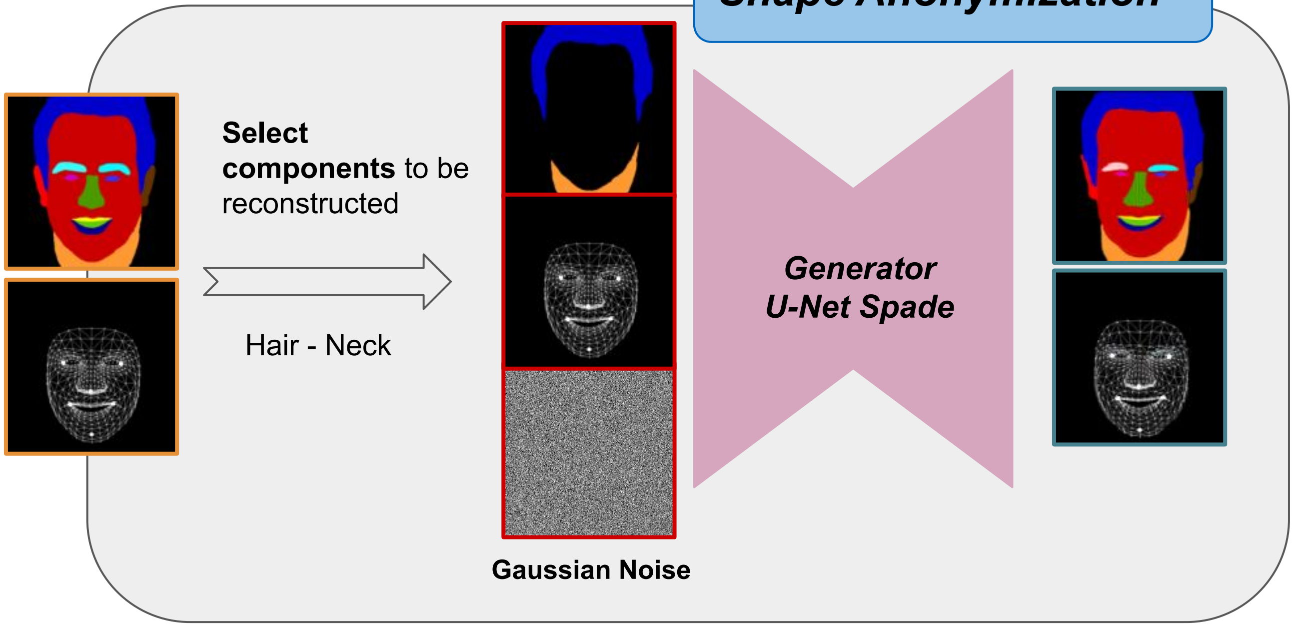
Preprocessing

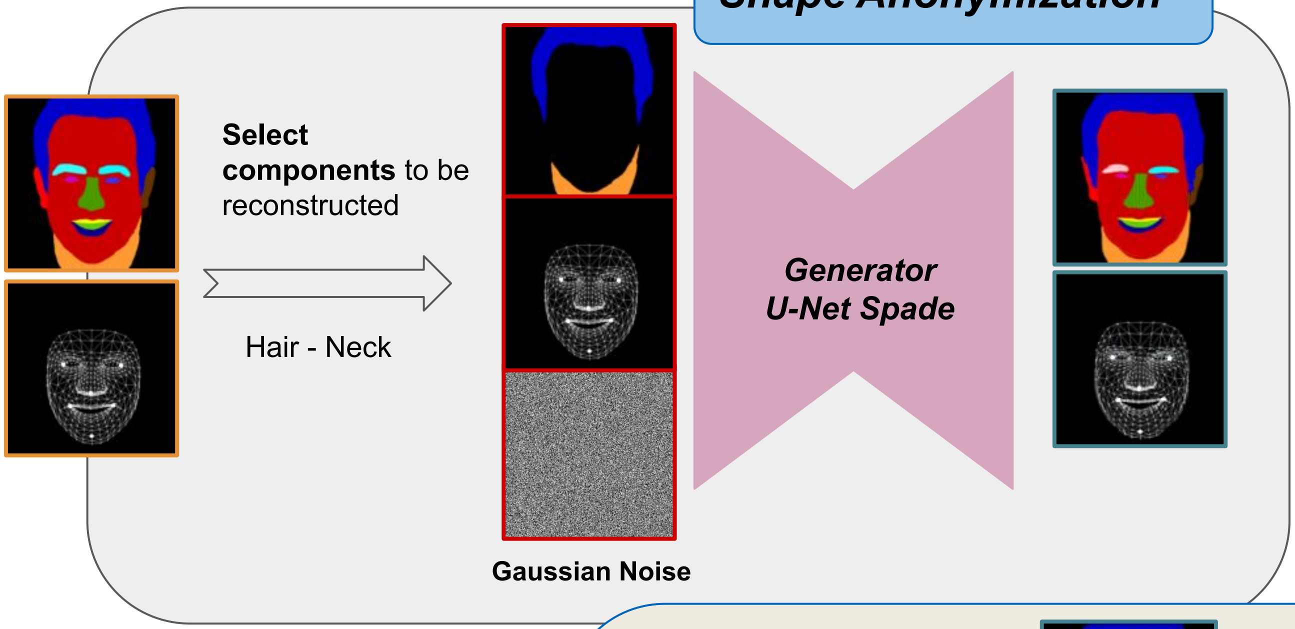


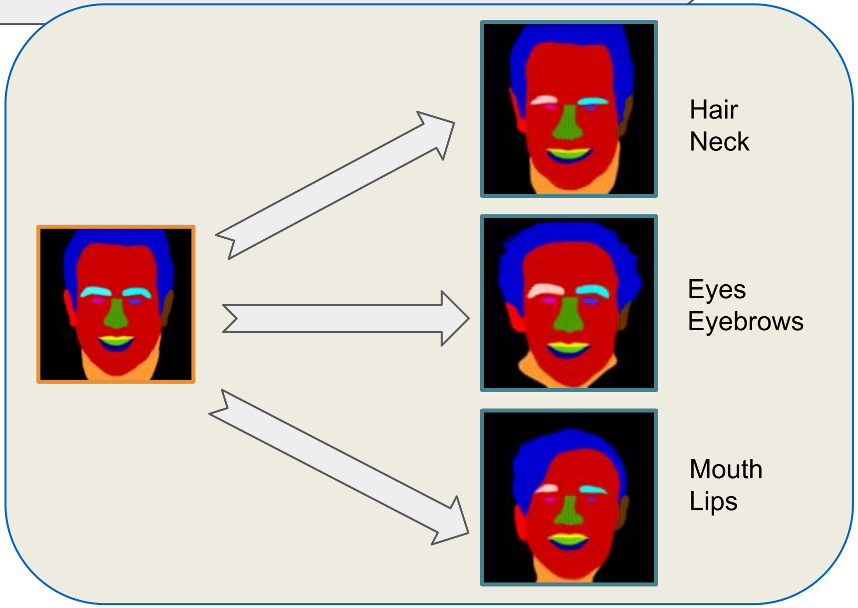
- Dlib Detector
- Face Parsing
- MediaPipe
- **Background Inpainting**

Shape Anonymization

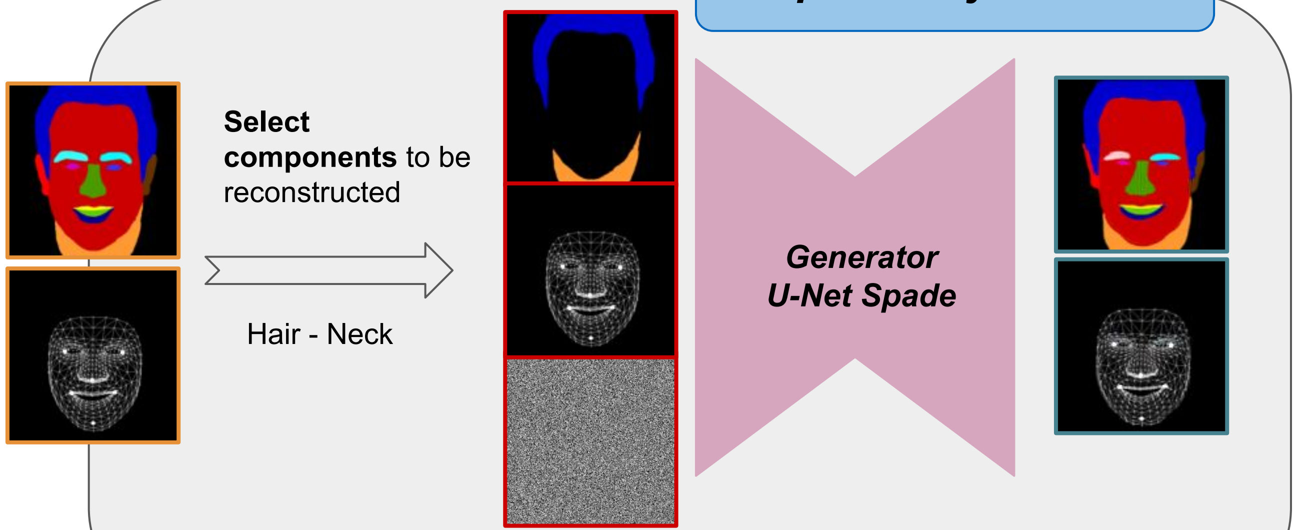


Shape Anonymization





Shape Anonymization

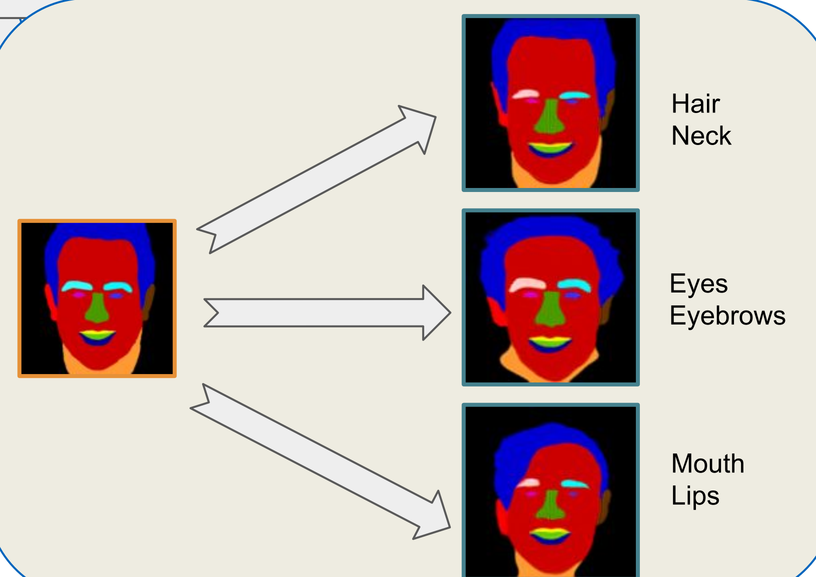


I. GAN Loss

II. L1 Loss

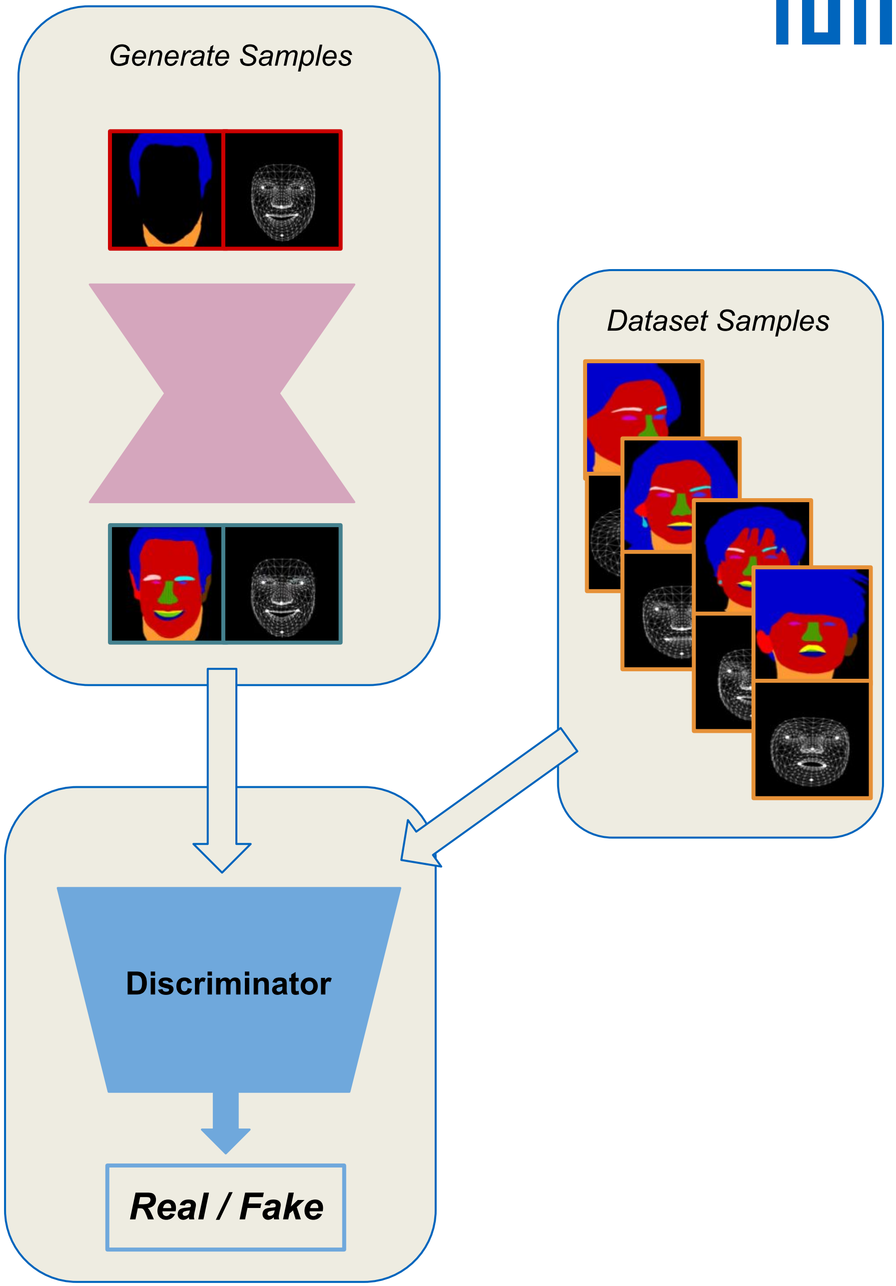
- Reconstruction
- Negative Reconstruction
- Hair Excess

III. Diversity Contrastive Loss



Loss Functions

I. ***GAN Loss***



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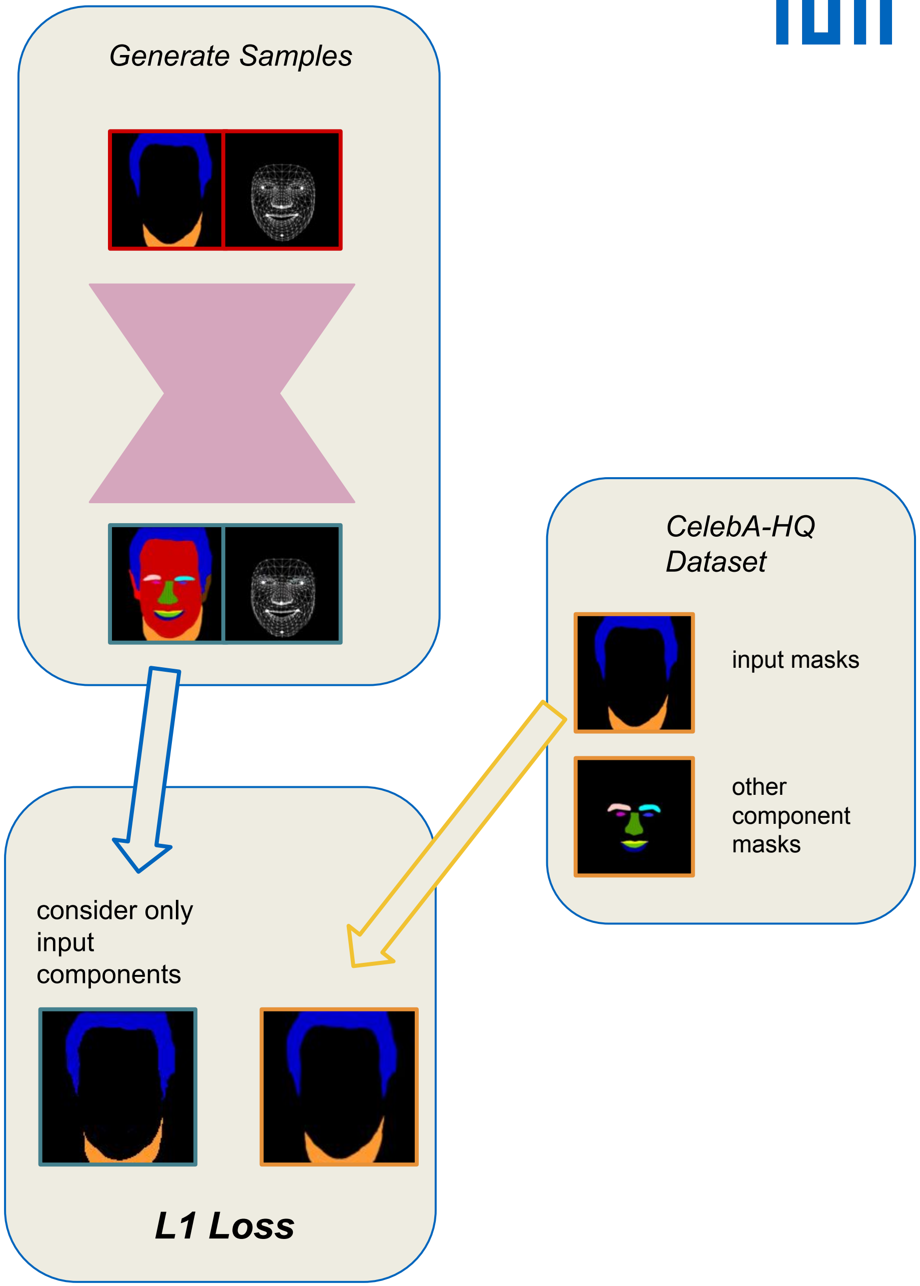
Loss Functions

I. GAN Loss

II. L1 Losses

1. Reconstruction Loss



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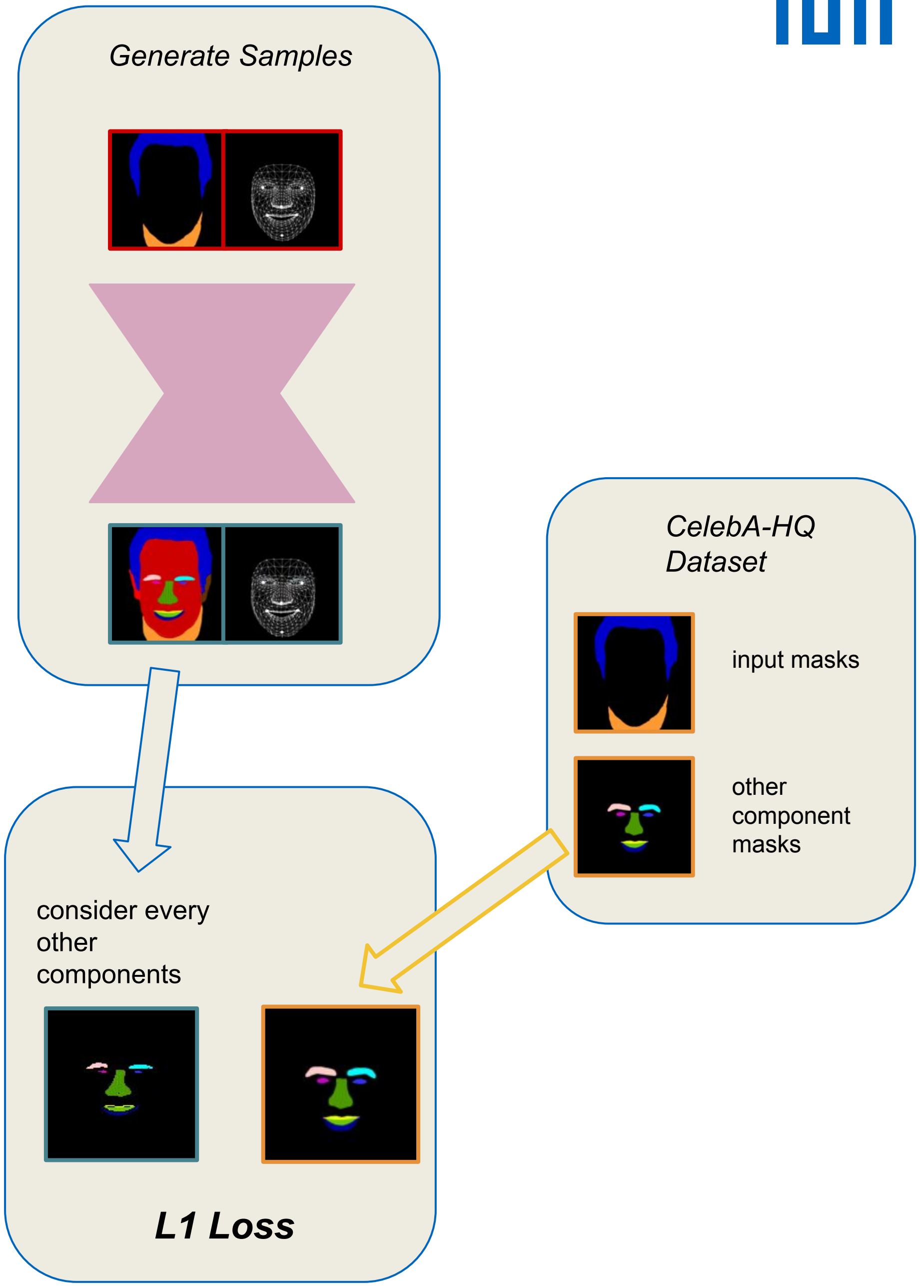
Loss Functions

I. GAN Loss

II. L1 Losses

1. Reconstruction Loss

2. Negative Reconstruction Loss



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Loss Functions

I. ***GAN Loss***

II. ***L1 Losses***

   1. *Reconstruction Loss*
   2. *Negative Reconstruction Loss*
   3. *Hair Excess Loss*

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Loss Functions

I. GAN Loss

II. L1 Losses
   1. Reconstruction Loss
   2. Negative Reconstruction Loss
   3. Hair Excess Loss

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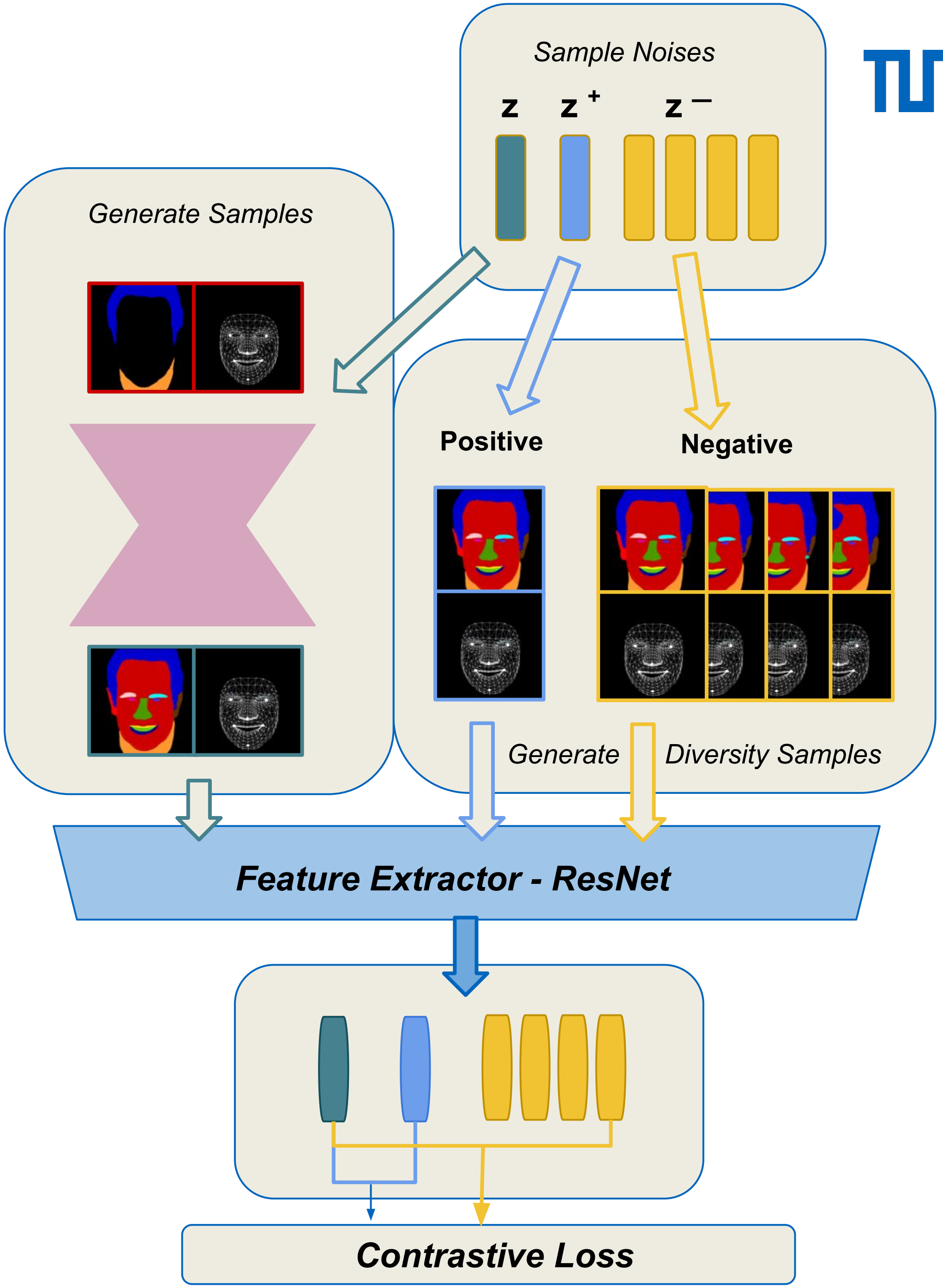
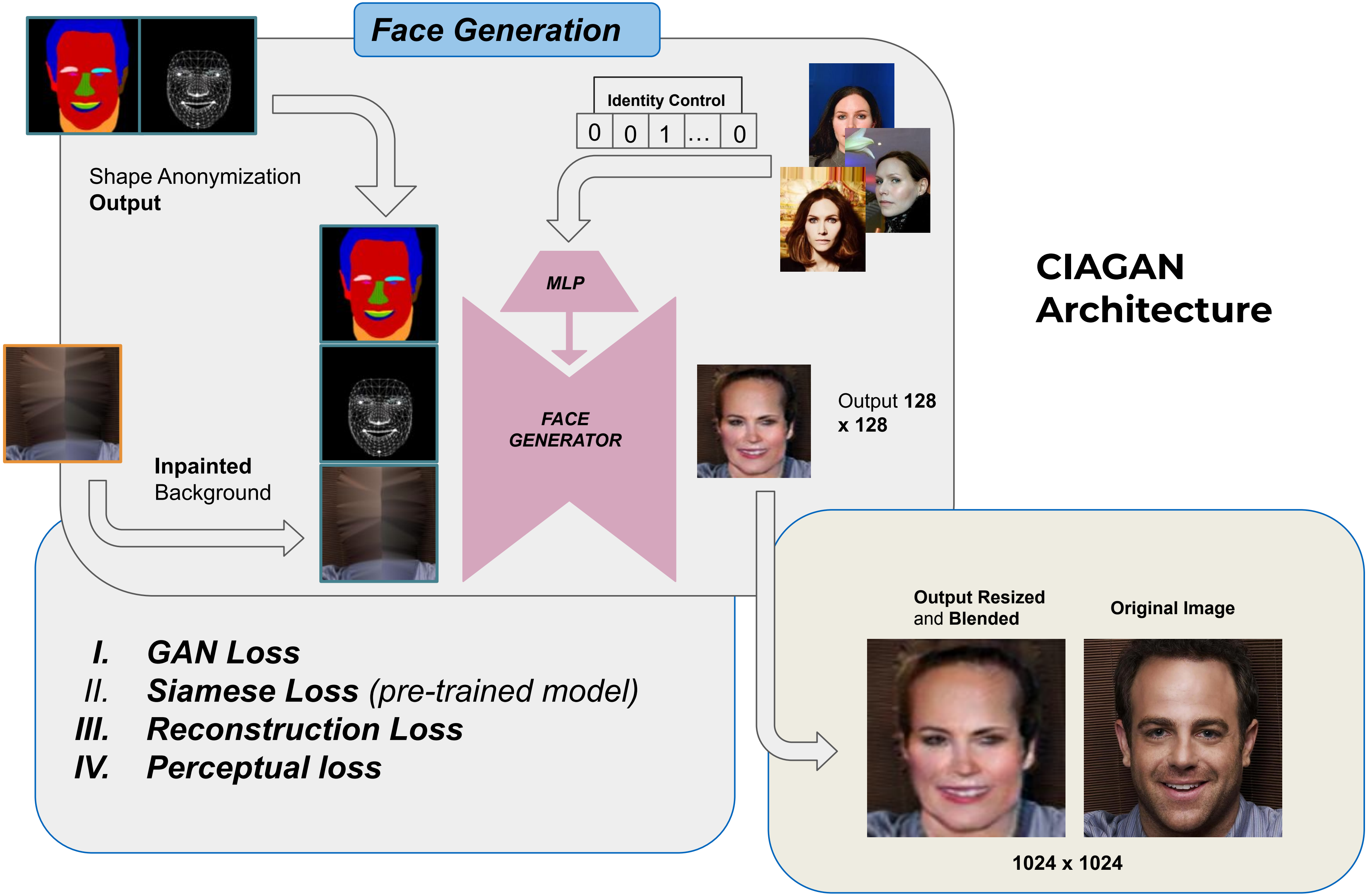


Liu, R., et al 2019

CIAGAN Architecture



1. ***GAN Loss***
2. ***Siamese Loss*** *(pre-trained model)*
3. ***Reconstruction Loss***
4. ***Perceptual loss***

Datasets

- Aligned and cropped images
- Resolution 178 x 218
- Only identities with at least 30 images

Liu, Z., et al 2015

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Datasets

- Aligned and cropped images
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- Only identities with at least 30 images

- 30.000 High Quality images selected from CelebA (1024 x 1024)
- Corresponding facial segmentation masks with 19 classes (512 x 512)

Lee, C. et al. 2020

Datasets

- Aligned and cropped images
- Resolution 178 x 218
- Only identities with at least 30 images

- 30.000 High Quality images selected from CelebA (1024 x 1024)
- Corresponding facial segmentation masks with 19 classes (512 x 512)

Face Forensics ++

- 1.000 video sequences
- Trackable face without occlusions

Rössler, A. et al. 2019

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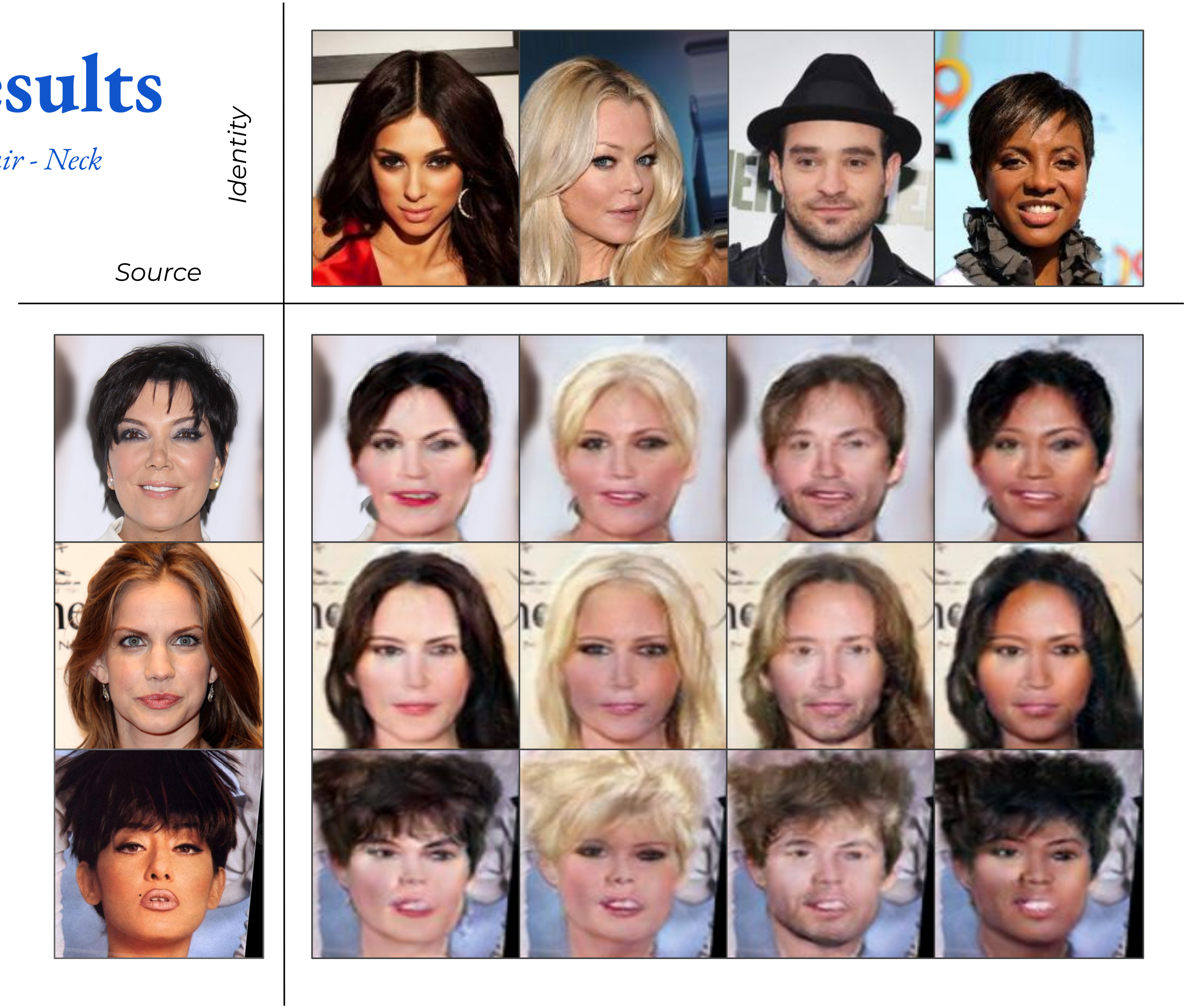
Results

Hair - Neck



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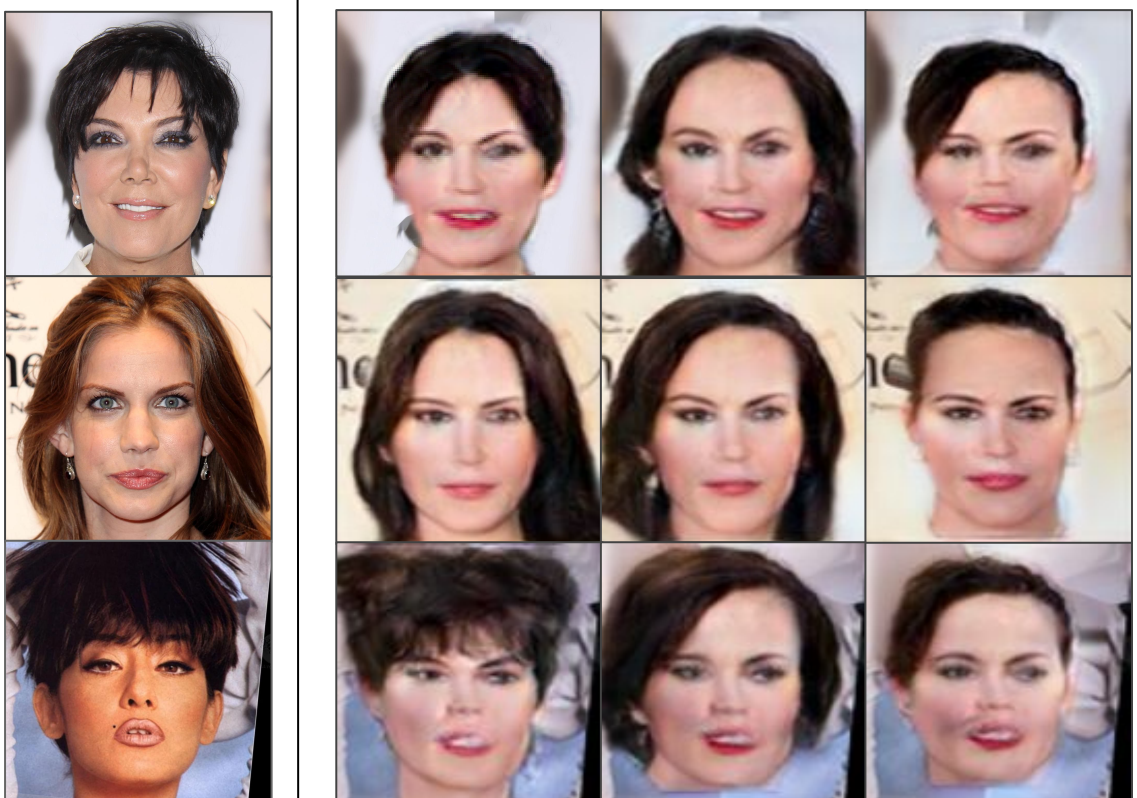
Results

Constraints

Hair Neck | *Eyes Eyebrows Nose* | *Mouth Lips*

Source



Evaluation - Main Results

Models	**Detection (↑)**		**Identification (↓)**
	Dlib	SSH	FaceNet
Original	100	100	95.44
Pixelization 8 by 8	0	0	**0.43**
Blur 9 by 9	93.58	33.87	73.34
Blur 17 by 17	82.05	0.33	24.67
CIAGAN Baseline	99.73	54.38	2.94
Thesis Model	**99.80**	**65.43**	1.20

Evaluation - Main Results

Wanted Parts	**Detection (↑)**		**Identification(↓)**	**FID (↓)**	**LPIPS(↑)**
	Dlib	SSH	FaceNet		
Hair, Neck	**99.80**	65.43	1.20	**67.11**	0.025
Mouth, Lips	99.61	72.10	1.08	94.77	0.141
Eyes, Eyebrows	99.85	**72.15**	0.82	83.94	0.214
Everything	99.78	69.89	1.27	68.85	0.021
Nothing	99.72	67.14	**0.73**	88.44	**0.226**
CIAGAN Baseline	99.73	54.38	2.85	71.95	0.107

Evaluation - Ablation Study

Models Evaluation on Neck, Hair	**Detection (↑)** Dlib	**Identification (↓)**	**FID (↓)**	**LPIPS (↑)**
Thesis Model	99.80	1.20	**67.11**	0.025
Full Segmentation Mask	99.18	1.20	71.70	0.049
No Face Mesh	1.09	**0.22**	142.72	**0.229**
No Orientation Landmarks	99.59	0.46	71.93	0.103
No Reconstruction Loss	0.41	0.33	274.77	0.225
No Inverse Reconstruction Loss	99.61	1.15	72.77	0.065
No Diversity Loss	**99.92**	0.29	85.55	0.045

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Evaluation - Ablation Study

Models	Hair, Neck		Mouth, Lips		Eyes, Eyebrows		Everything		Nothing	
Evaluation on Neck, Hair	FID (↓)	LPIPS (↑)	FID	LPIPS	FID	LPIPS	FID	LPIPS	FID	LPIPS
Thesis Model	**67.11**	0.025	94.77	0.141	83.94	0.214	**66.85**	0.021	88.44	0.226
Full Segmentation Mask	71.70	0.049	**72.11**	0.050	**72.35**	0.051	74.60	0.051	**75.00**	0.051
No Face Mesh	142.72	**0.229**	204.33	**0.356**	266.22	**0.362**	132.93	0.134	253.08	**0.345**
No Orientation Landmarks	71.93	0.103	89.75	0.173	86.66	0.192	73.02	0.074	85.53	0.196
No Reconstruction Loss	274.77	0.225	277.76	0.277	274.21	0.278	274.98	**0.213**	274.34	0.282
No Inverse Reconstruction Loss	72.77	0.065	95.09	0.095	85.13	0.144	71.75	0.036	85.36	0.147
No Diversity Loss	85.55	0.045	106.39	0.035	91.46	0.048	100.42	0.018	96.58	0.064

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Evaluation - Video

Models Evaluation on Neck, Hair	**PSNR (↑)**	**LPIPS (↓)**	**tOF (↓)**	**tLP (↓)**
Thesis Model	21.66	0.133	1.02	5.97
CIAGAN Baseline	**25.99**	**0.077**	**0.22**	**1.65**

Conclusion

- Full Anonymization Pipeline
- Good detection and de-identification rates
- Flexible shape anonymization model to improve control over the generated images, including on neck and hair
- The pipeline generates realistic faces, however the blending step could be improved

THANK YOU

Candidate: Filippo Simonazzi

Supervisor: Maxim Maximov

Advisor: Prof. Dr. Laura Leal-Taixe

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