GPU TECHNOLOGY CONFERENCE

NVIDIA

Fashion Design with GANs: Disentangling Color, Texture, and Shape

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Fashion E-Commerce @ zalando

~ 4.5 billion EUR
revenue 2017

> 200 million
visits per month

> 15,000
employees in Europe

> 70%
of visits via mobile devices

> 23 million
active customers

> 300,000
product choices

~ 2,000
brands

15
countries

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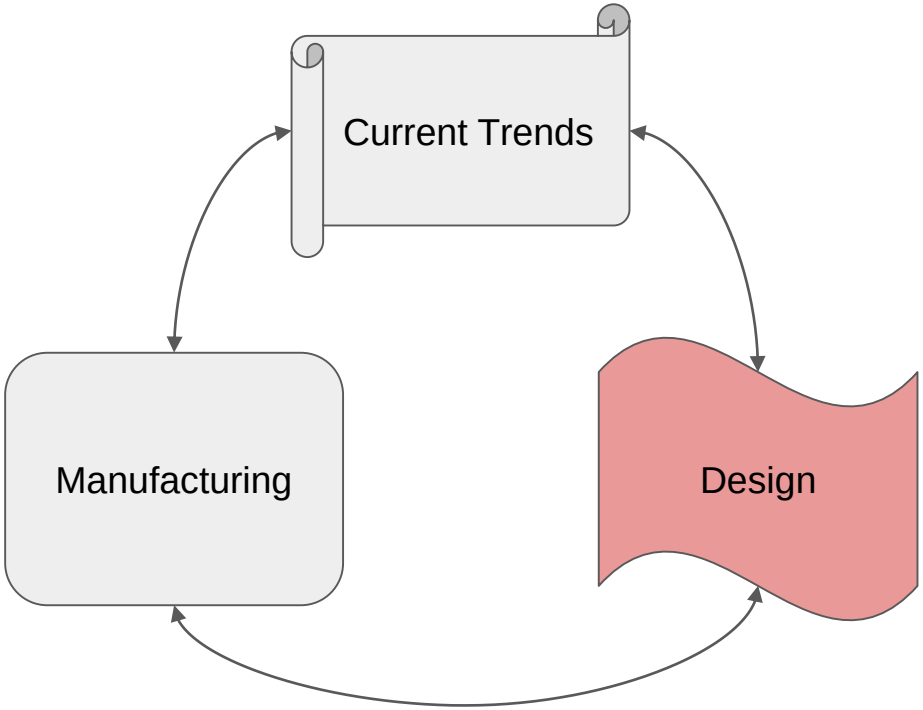
Fashion Design at Zalando



How can computers help speed-up the process?

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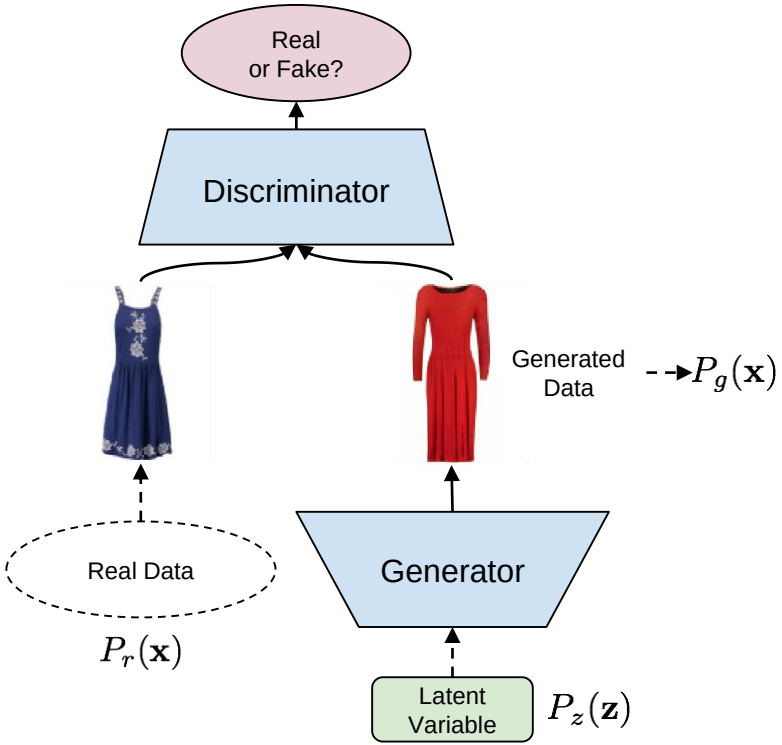
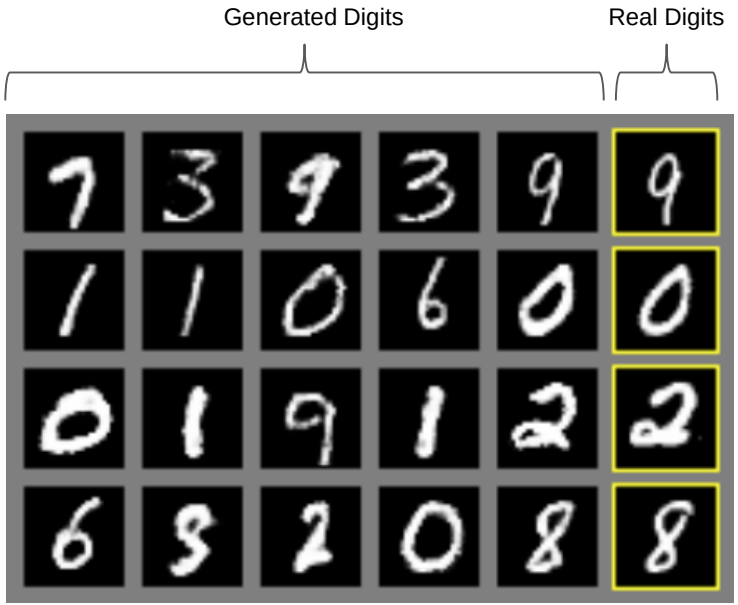
Generative Adversarial Networks (GANs)

(Goodfellow et. al., 2014)

- Train two neural networks in an adversarial setting





(LeCun and Cortes, 1998)

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GANs and Fashion

Swapping Clothes in Photos

The Conditional Analogy GAN: Swapping Fashion Articles on People Images (Jetchev and Bergmann, 2017)

Clothing Texture Design

Fashion Style Generator (Jiang and Fu, 2017)

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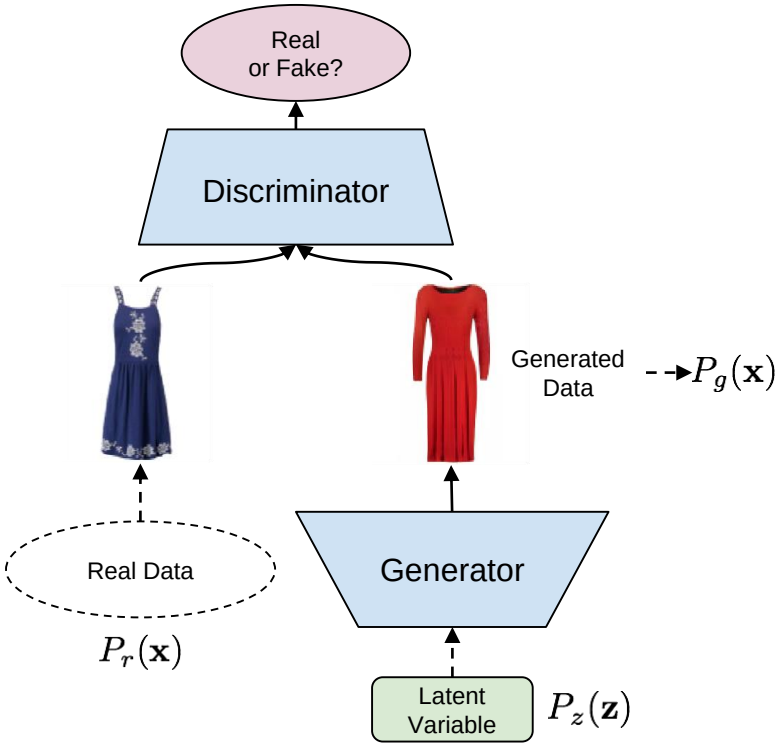
Attribute Control and Disentangling



- Attribute control
  - Color
  - Texture
  - Shape
- Disentangle
  - Each attribute has a separate effect
  - Changing one should not change the other

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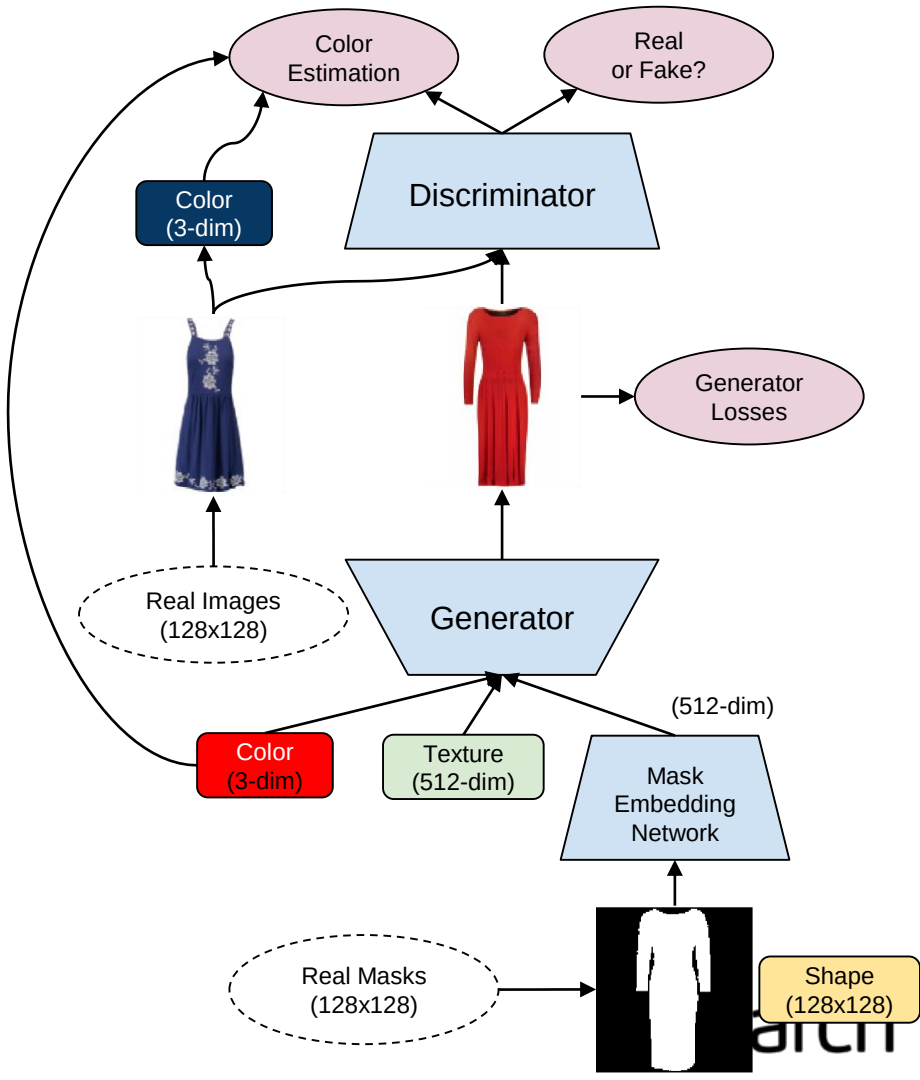
Our Model

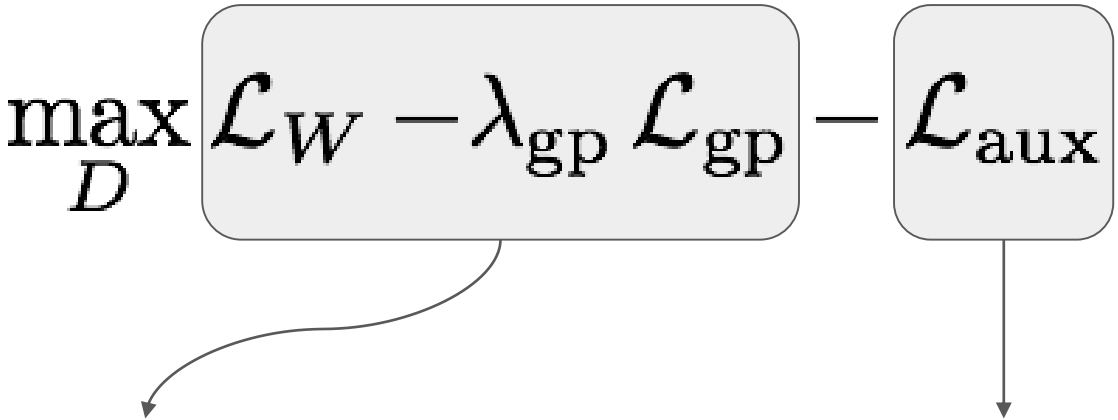
- Attribute Data
  - $\mathbf{c}$ Color
    - 3-dim
    - RGB
  - $\mathbf{t}$ Texture (local structure, pattern)
    - 512-dim
  - $\mathbf{s}$ Shape (segmentation mask)
    - Embedded first
    - 512-dim

$$\mathbf{x} = G(\mathbf{c}, \mathbf{t}, \mathbf{s})$$

Generated Image



Discriminator Losses



“Improved Training of Wasserstein GANs”
(Gulrajani et. al., 2017)

“Conditional Image Synthesis With Auxiliary Classifier GANs
(Odena et. al., 2017)

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Generator Losses

- Color Consistency
- Texture Consistency
- Shape Consistency
- Generator Color Check

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Color Consistency

$\mathbf{c}$ color

$\mathbf{t}$ texture

$\mathbf{s}$ shape

$$\mathbf{x}_1 = G(\mathbf{c}, \mathbf{t}_1, \mathbf{s}_1) \qquad \mathbf{x}_2 = G(\mathbf{c}, \mathbf{t}_2, \mathbf{s}_2)$$

Average Dress Color

$$A(\mathbf{x}, \mathbf{s}) = \frac{1}{|\mathbf{s}|} \sum_{i,j} \mathbf{s}(i,j) \cdot \mathbf{x}(i,j)$$

Color Consistency Loss $\longrightarrow \left|\left| A(\mathbf{x}_1, \mathbf{s}_1) - A(\mathbf{x}_2, \mathbf{s}_2) \right|\right|_2^2$

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Texture Consistency

- Laplacian matting matrix
  - (NxN image → N^2xN^2 matrix)
  - A Closed Form Solution to Natural Image Matting (Levin et. al., 2006)

Input Image (with markings)

Estimated Matte

Texture Consistency

$\mathbf{c}$ color

$\mathbf{t}$ texture

$\mathbf{s}$ shape

$$N \times N \times 3 \longleftarrow \mathbf{x}_1 = G(\mathbf{c}_1, \mathbf{t}, \mathbf{s}_1) \qquad \mathbf{x}_2 = G(\mathbf{c}_2, \mathbf{t}, \mathbf{s}_2)$$

$$N^2 \times 3 \longleftarrow \mathbf{v}_1 \qquad \mathbf{v}_2$$

Texture Consistency Loss

$$\mathrm{Tr}(\mathbf{v}_1^T \mathbf{L}_2 \mathbf{v}_1 + \mathbf{v}_2^T \mathbf{L}_1 \mathbf{v}_2)$$

$$N^2 \times N^2 \longleftarrow \mathbf{L}_1 \longleftarrow \text{Laplacian Matrices} \longrightarrow \mathbf{L}_2$$

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Shape Consistency

$\mathbf{c}$ color

$\mathbf{t}$ texture

$\mathbf{s}$ shape

$$\mathbf{x} = G(\mathbf{c}, \mathbf{t}, \mathbf{s})$$

$\mathbf{s}$

Shape Consistency Loss $\longrightarrow B(\mathbf{x}, \mathbf{s}) = \frac{1}{|1 - \mathbf{s}|} \sum_{i,j} (1 - \mathbf{s}(i,j)) \cdot ||\mathbf{x}(i,j) - \mathbf{b}||_1$

Background Color $\longrightarrow \mathbf{b} = [1, 1, 1]$

Generator Color Check

$\mathbf{c}$ color

$\mathbf{t}$ texture

$\mathbf{s}$ shape

$$\mathbf{x}^{\mathbf{c}} = G(\mathbf{c}, \mathbf{t}, \mathbf{s})$$

Average Dress Color

$$A(\mathbf{x}^{\mathbf{c}}, \mathbf{s})$$

Generator Color Check → $$||\mathbf{c} - A(\mathbf{x}^{\mathbf{c}}, \mathbf{s})||_2^2$$

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Experiments & Results

- Modified the code from *
- Directly generate 128x128 pixel images
- NVIDIA P100 GPU → 1 week of training
- Dataset → 120,000 dresses from Zalando
- ADAM Optimizer (LR=0.001, B1=0, B2=0.99) (Kingma and Ba, 2014)

*Progressive Growing of GANs for Improved Quality, Stability, and Variation (Karras et. al., 2018)

Color Control

$$G(\mathbf{c}_i, \mathbf{t}, \mathbf{s})$$

- Changing color
- Texture and shape stay the same

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Texture Control

$$G(\mathbf{c}, \mathbf{t}_i, \mathbf{s})$$

- Changing texture
- Color and shape stay the same

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Shape Control

$$G(\mathbf{c}, \mathbf{t}, \mathbf{s}_i)$$

- Changing shape
- Color and texture stay the same

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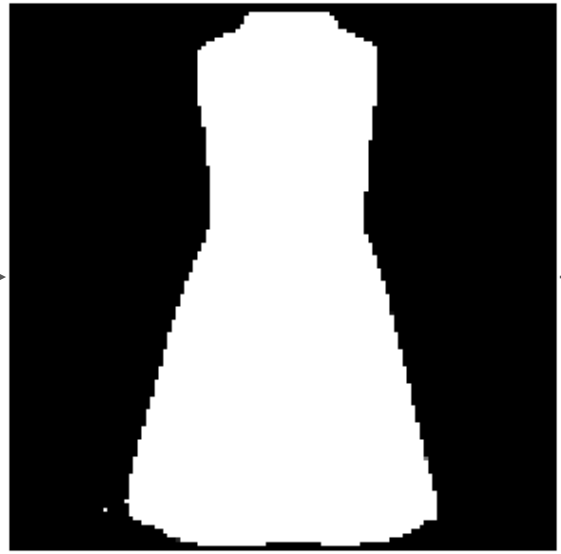
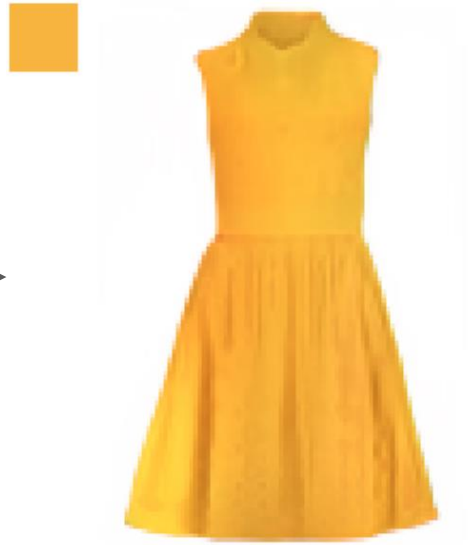
DEMO

Fashion Design

Real Article



Estimated Shape Mask



Reconstructed Article

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Fashion Design

Failure Cases

Real Article

Estimated Shape Mask

Reconstructed Article

What’s Next?

- Improve upon the design model
  - Allow for multiple colors/color histograms
  - More attributes
  - Direct texture input

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Thank You!

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Preserving Local Structure

Deep Photo Style Transfer
(Luan et. al., 2017)

(a) Input image

(b) Neural Style

(c) CNNMRF

(d) Our result

(e) Reference style image

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Laplacian Matrix

$$\mathbf{L}(i,j) = \sum_{k|(i,j)\in w_k} \left(\delta_{ij} - \frac{1}{|w_k|} \left(1 + (I_i - \mu_k)(\Sigma_k + \frac{\epsilon}{|w_k|})^{-1}(I_j - \mu_k) \right) \right)$$

$|w_k|$ Size of the neighborhood

μ_k Mean color vector (within neighborhood)

Σ_k Color covariance matrix (within neighborhood)

Controlling the Color

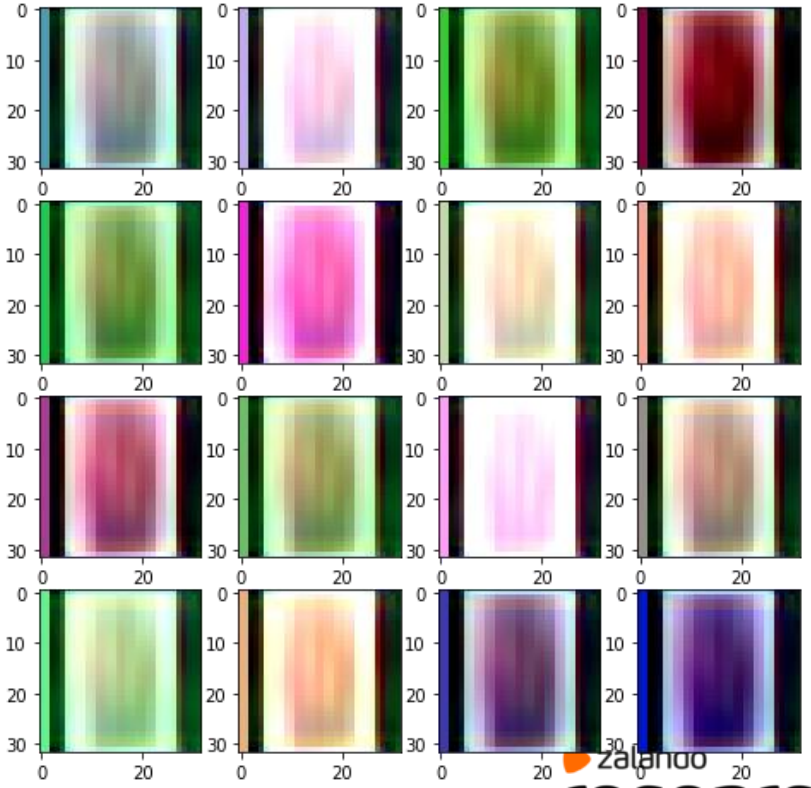
- Start small (32x32)
- Latent Vector + Color input (RGB)
- Pro:
  - We get the desired color
- Con:
  - Color input changes the shape

Same latent vector - Different colors

Adding Shape Consistency

- Shape consistency with Laplacian Matting matrices

- Weighting between color and shape control



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