A Neural Algorithm of Artistic Style

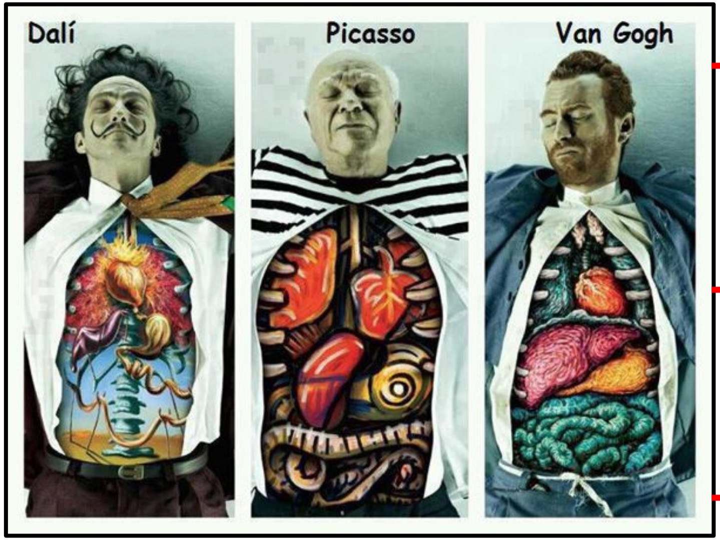
Leon A. Gatys et. al

arXiv 2015

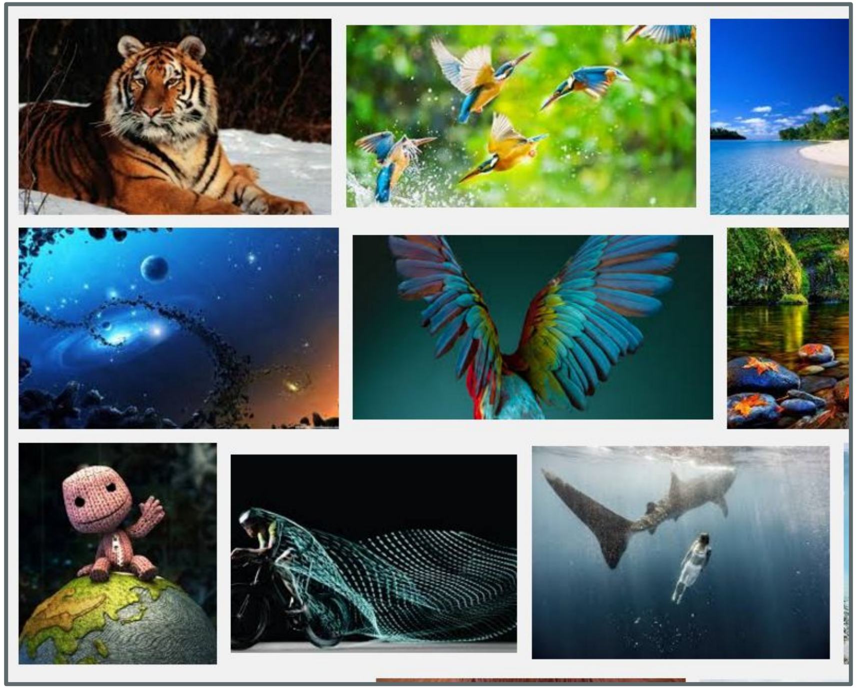
Presented by Jackie Chu

The Question

Can we apply **any** style to **any** content?



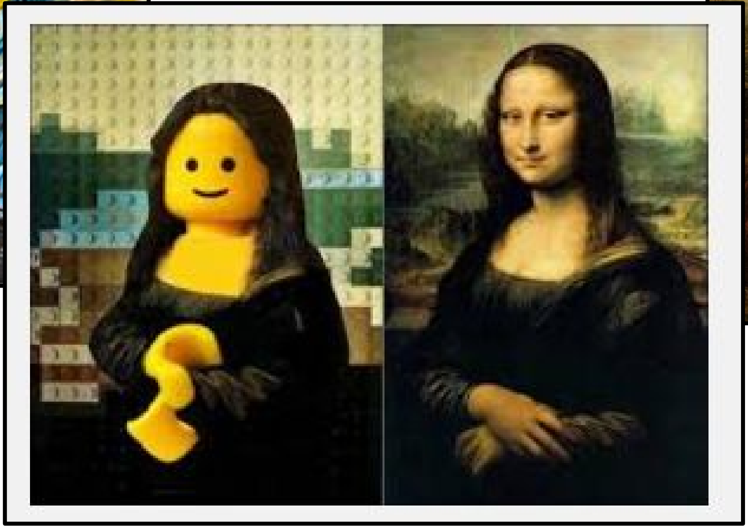
MASP Art School campaign done by DDB Brazil



Google search on "images"

“Previous Work”

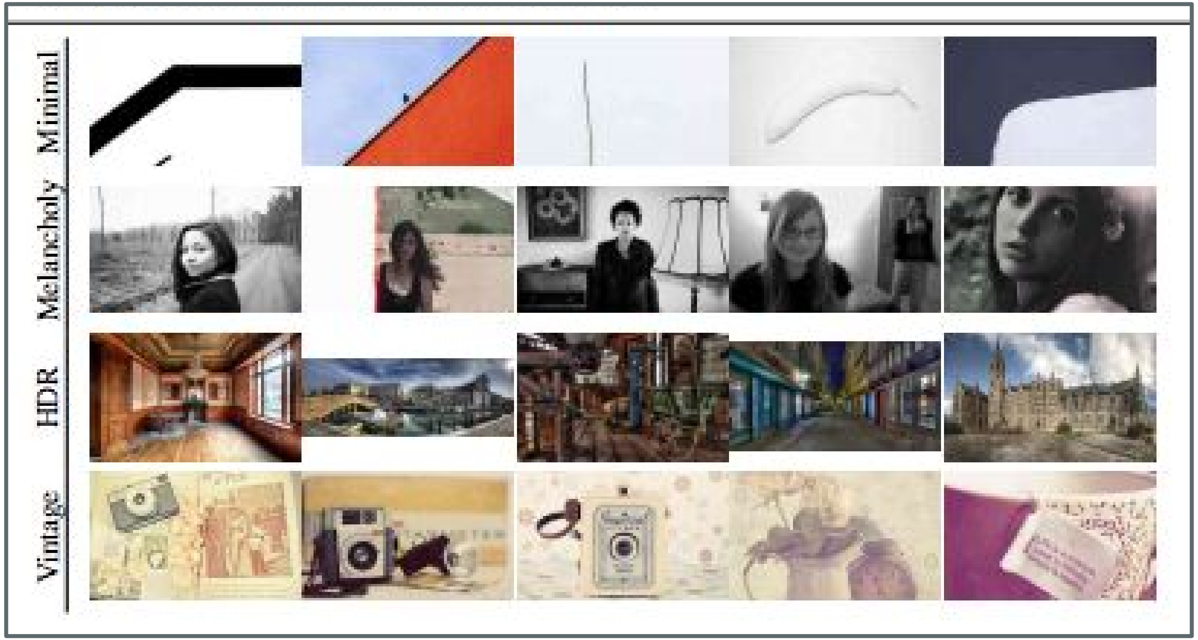
Print by James Hance



http://thirddime.com/blog/10_awesome_lego_versions_of_famous_paintings/

http://www.artfido.com/blog/artist-photoshops-her-fat-cat-into-famous-artworks/

Previous Work: Learning Styles



"We also show that **style is highly content-dependent**."

Karayev, Sergey, et al. "Recognizing image style." *arXiv* (2013).

Contributions

- Learn best pairing between **content** and **style**

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Contributions: Visual Results

https://youtu.be/cB84sgqlkR4?t=27

https://www.youtube.com/watch?v=g9BxlwlQWlc

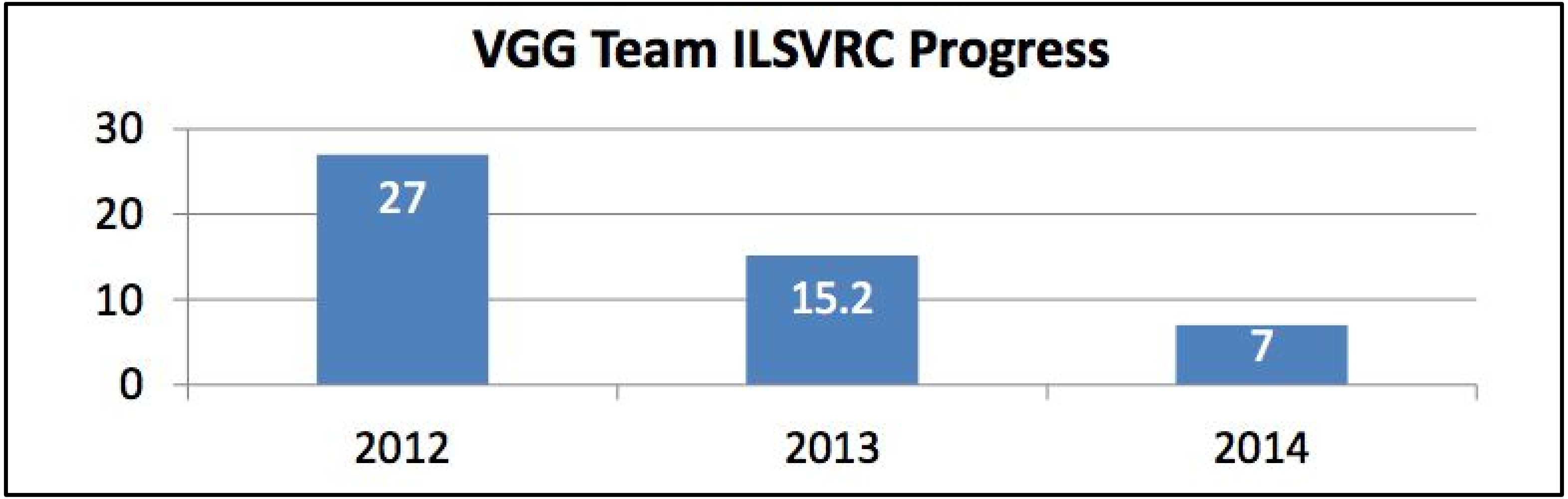
Methodology

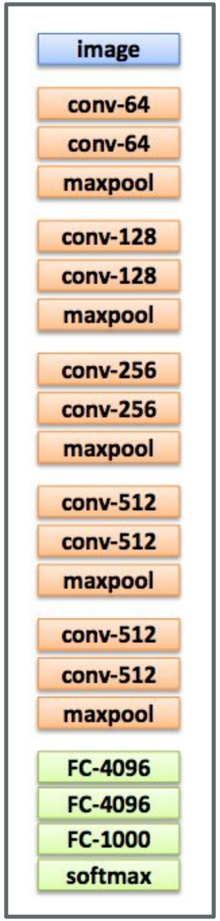
- Leverage CNNs
  - Trained for object recognition
- Jointly learn content and style
  - Texture synthesis captures style
  - Separate representations of content and style
  - Recombinations of content and style based on loss functions

Methodology

Very Deep ConvNets (VGG)

- **Key factors:** small kernels, stride of 1, ReLU, deeper depths





Slides at http://www.robots.ox.ac.uk/~karen/pdf/ILSVRC_2014.pdf

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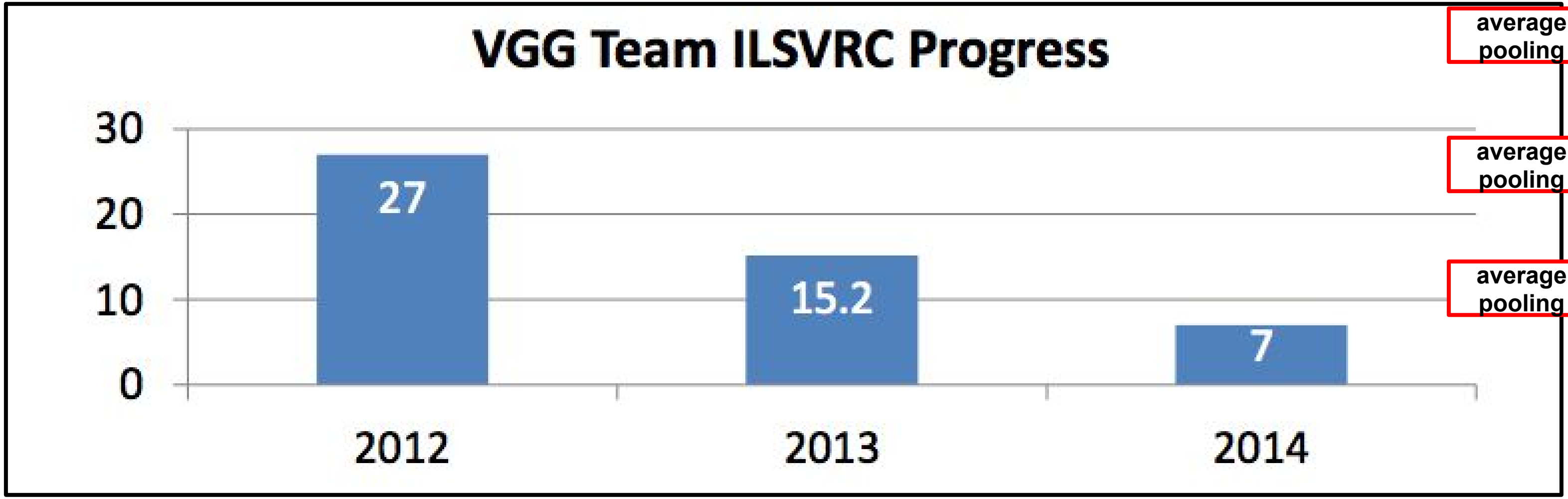
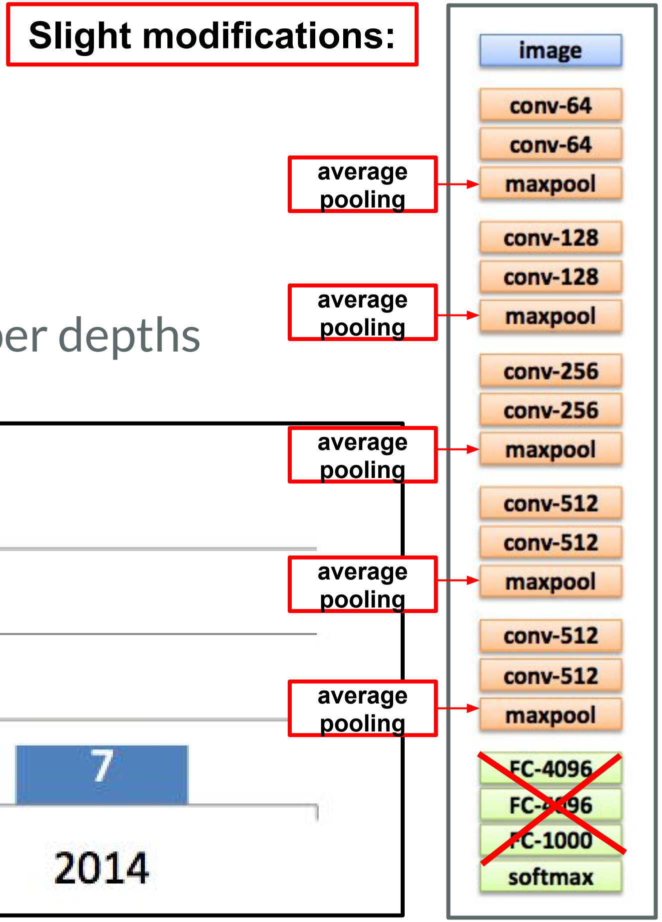


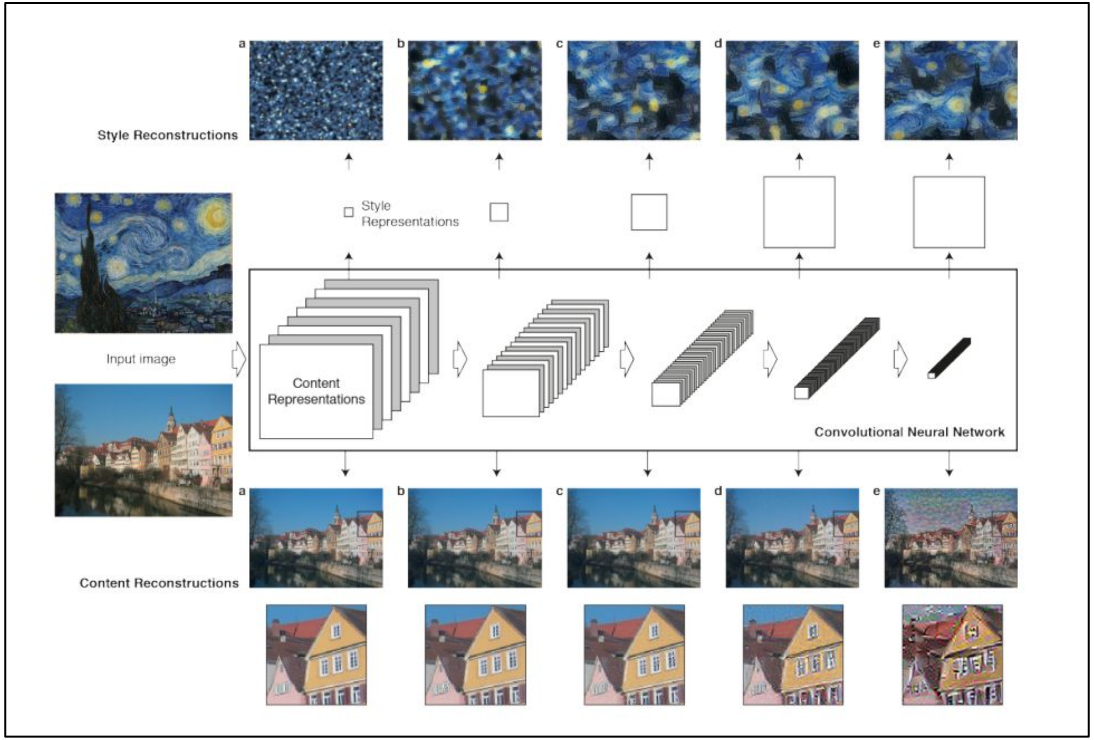


Slides at http://www.robots.ox.ac.uk/~karen/pdf/ILSVRC_2014.pdf

Methodology

- More flexibility!
- Content and style trained separately (for the most part)
  - Cannot have perfect synthesis → loss functions with its parameters

Methodology



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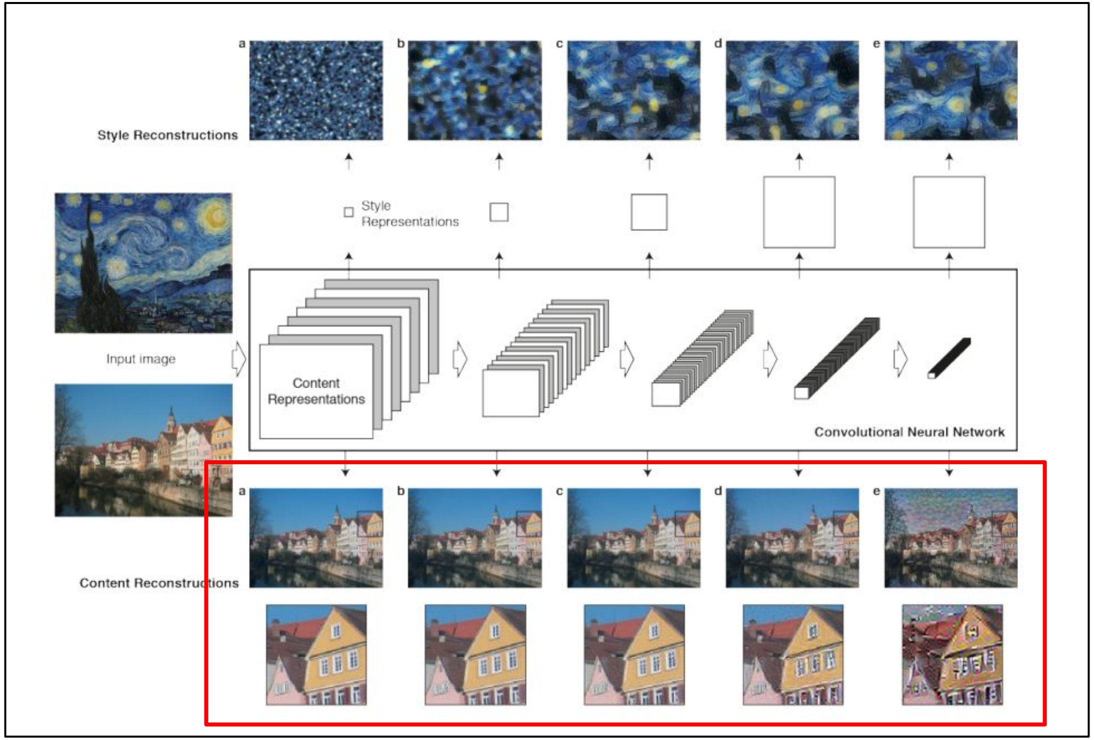
Methodology



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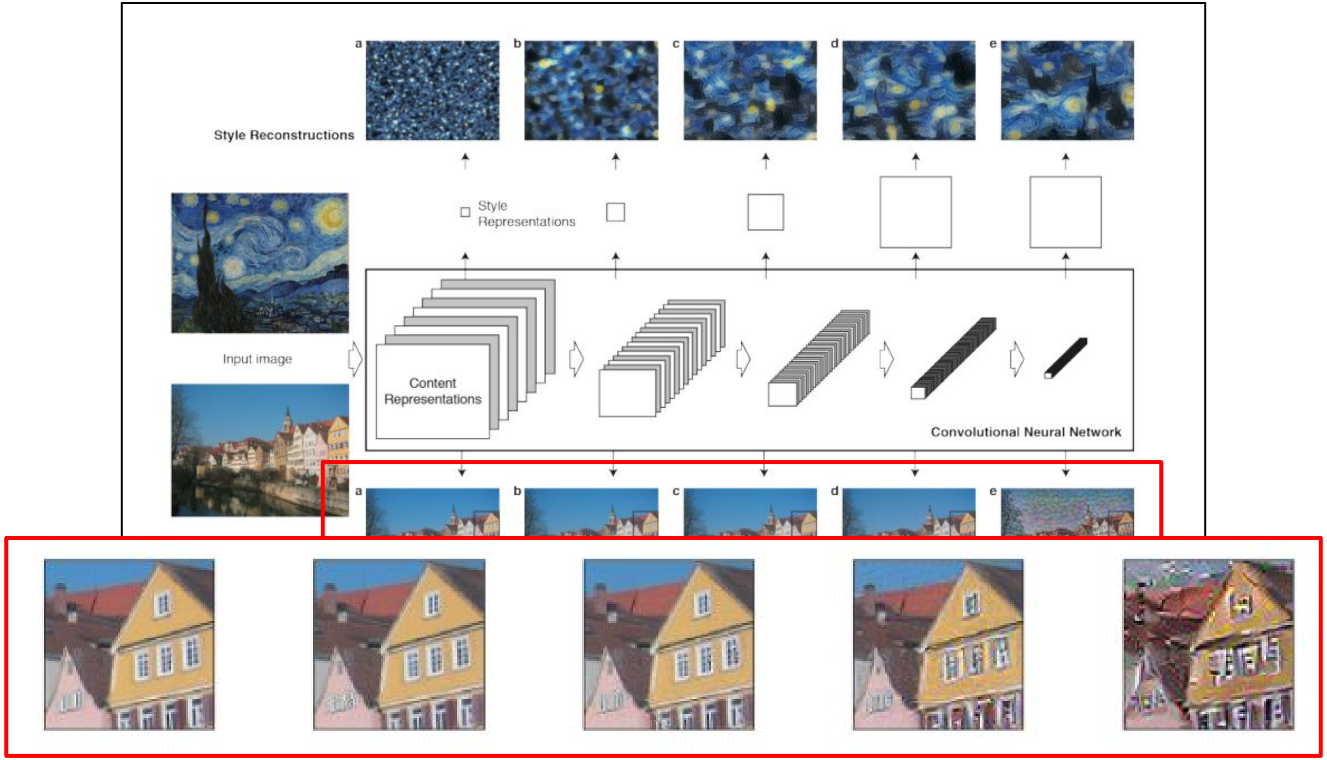

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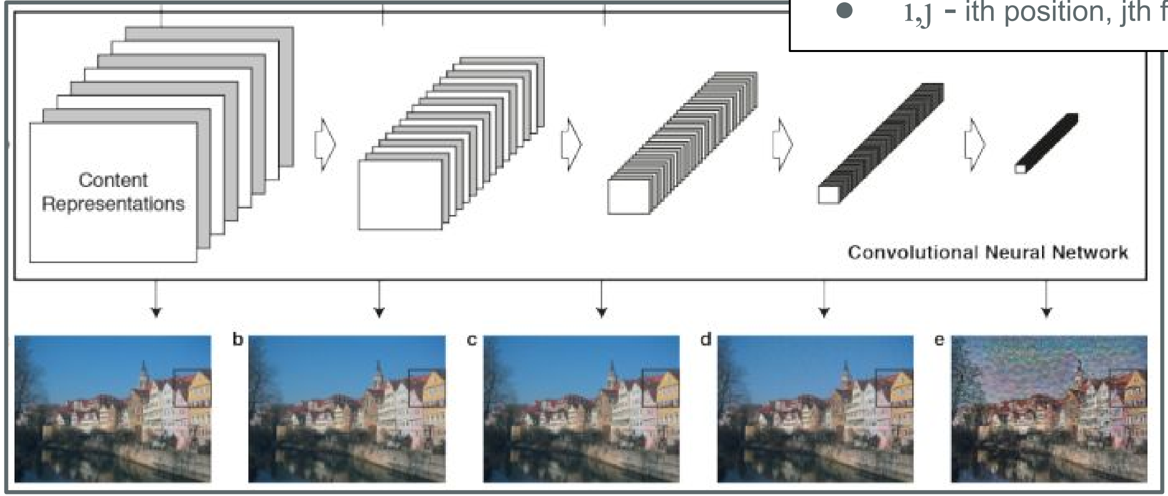
Loss Function: Content

- p - original image
- x - generated image
- F - responses stored in matrix
- P - feature representation of original image
- i,j - ith position, jth filter



$$\mathcal{L}_{content}(\vec{p}, \vec{x}, l) = \frac{1}{2} \sum_{i,j} \left(F_{ij}^{l} - P_{ij}^{l}\right)^2$$

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

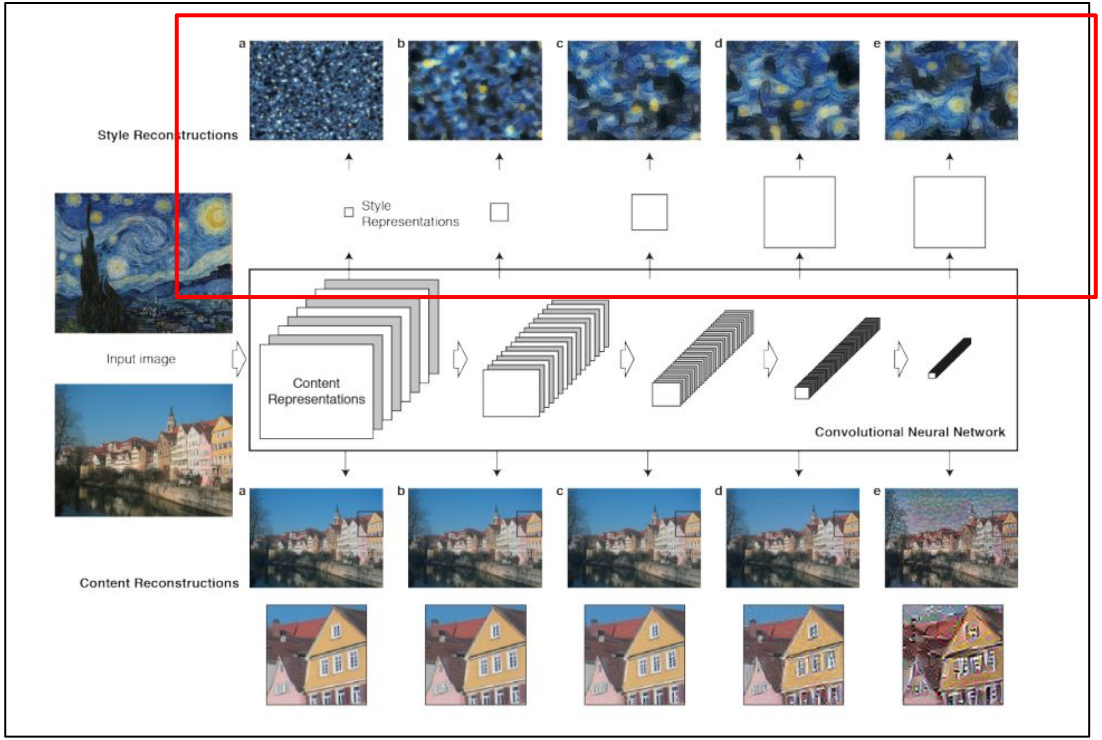
Loss Function: Content

$$\mathcal{L}_{content}(\vec{p}, \vec{x}, l) = \frac{1}{2} \sum_{i,j} \left(F^l_{ij} - P^l_{ij}\right)^2$$

$$\frac{\partial \mathcal{L}_{content}}{\partial F^l_{ij}} = \begin{cases} \left(F^l - P^l\right)_{ij} & \text{if } F^l_{ij} > 0 \\ 0 & \text{if } F^l_{ij} < 0 \,. \end{cases}$$

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Methodology



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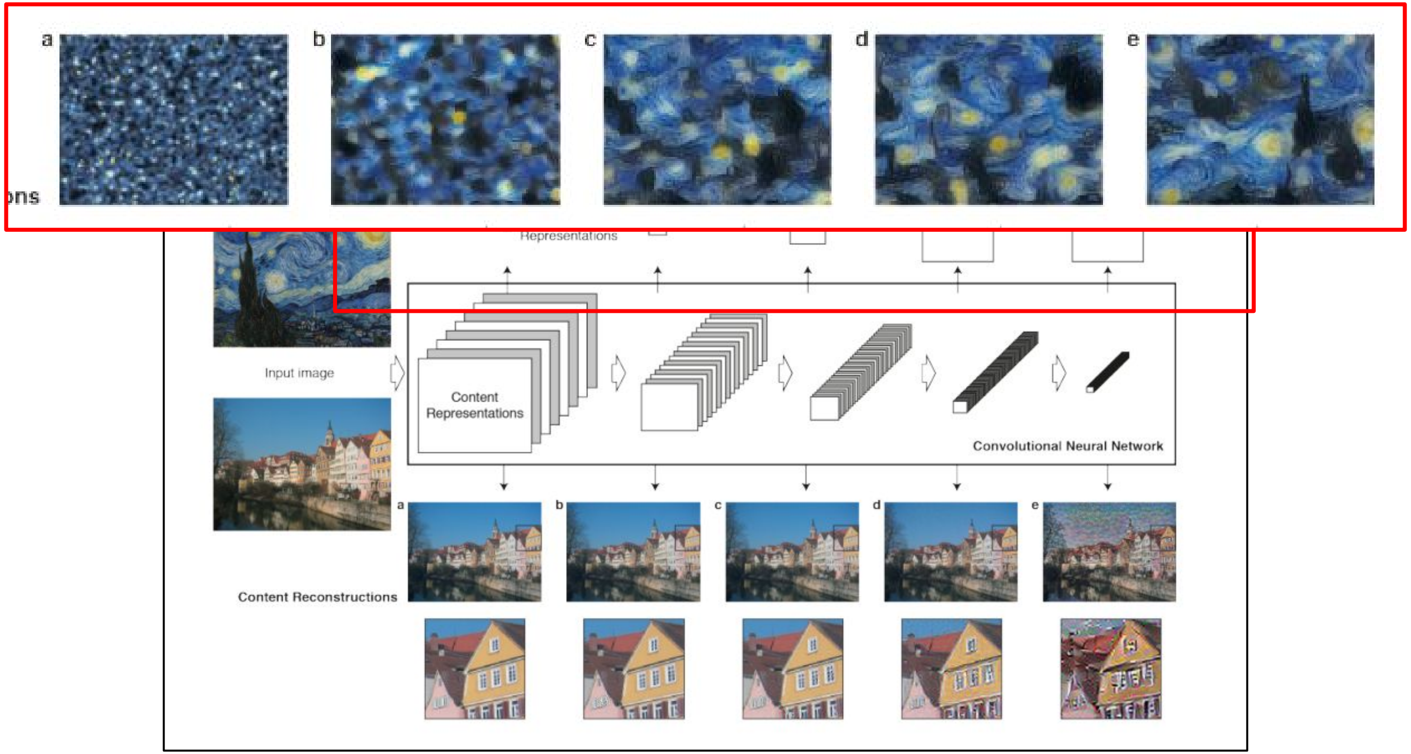
Methodology



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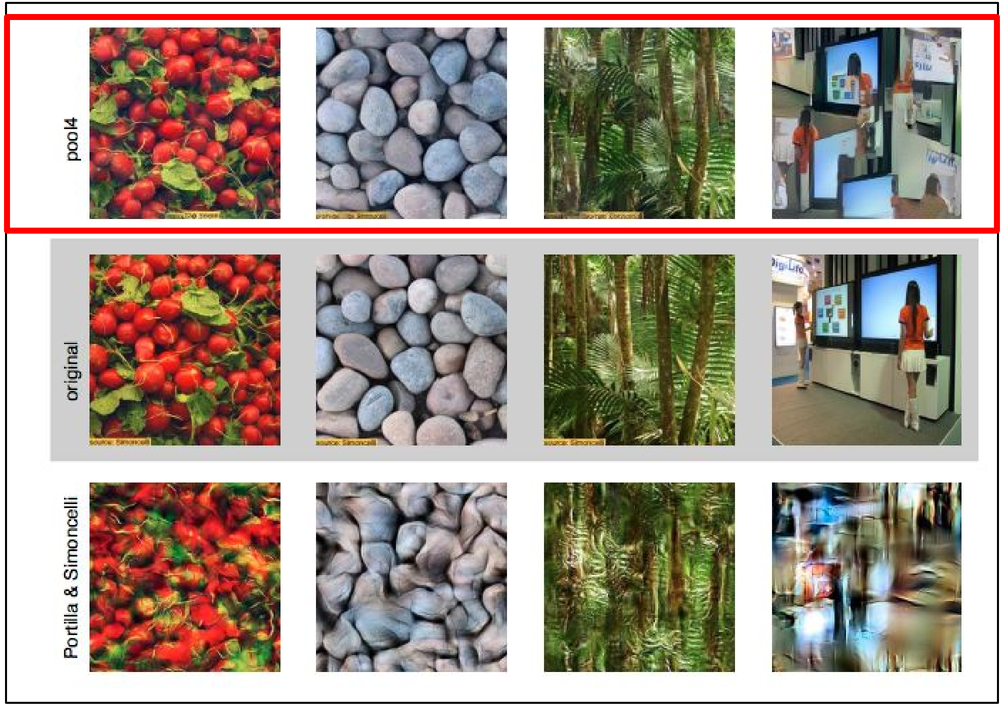
Methodology: Texture Synthesis

- As previously seen:
  - Create textures from feature representations
  - Discriminative
  - Captures salient features
  - Also uses VGG architecture



Gatys, Leon, et al. "Texture Synthesis Using Convolutional Neural Networks." arXiv (2015).

Loss Function: Style

$$E_l = \frac{1}{4N_l^2 M_l^2} \sum_{i,j} \left(G_{ij}^l - A_{ij}^l \right)^2$$

$$\mathcal{L}_{style}(\vec{a}, \vec{x}) = \sum_{l=0}^{L} w_l E_l$$

- G - content representation
- A - style representation
- a - original art image
- N, M - N feature maps of size M
- w - weight factors of layer l
- E - style loss at layer l

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Loss Function: Style

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$$\frac{\partial E_l}{\partial F_{ij}^l} = \begin{cases} \frac{1}{N_l^2 M_l^2} \left((F^l)^{\mathrm{T}} \left(G^l - A^l\right)\right)_{ji} & \text{if } F_{ij}^l > 0 \\ 0 & \text{if } F_{ij}^l < 0\,. \end{cases}$$

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Loss Function: Style

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$$\mathcal{L}_{style}(\vec{a},\vec{x}) = \sum_{l=0}^{L} w_l E_l$$

- w_l = 1/numActiveLayers with non-zero loss weight w_l

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Loss Function: All together

$$\mathcal{L}_{total}(\vec{p}, \vec{a}, \vec{x}) = \alpha \mathcal{L}_{content}(\vec{p}, \vec{x}) + \beta \mathcal{L}_{style}(\vec{a}, \vec{x})$$

- α and β are parameters to control regularization

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Loss Function: All together

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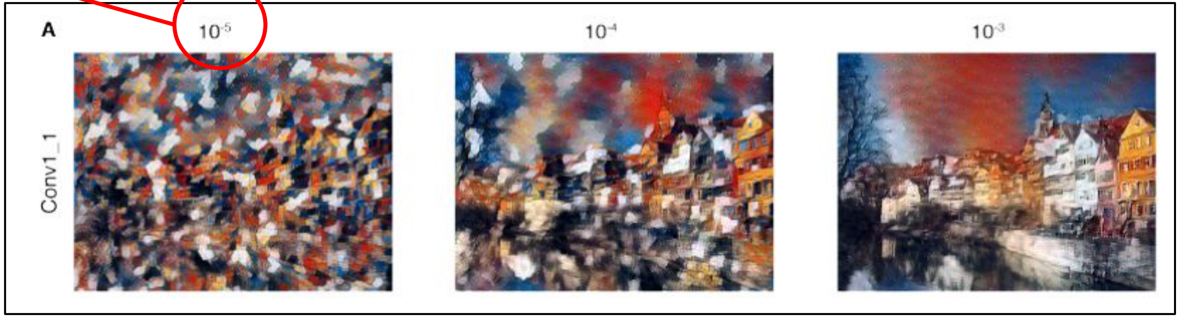
- α and β are parameters to control regularization
- alpha / beta



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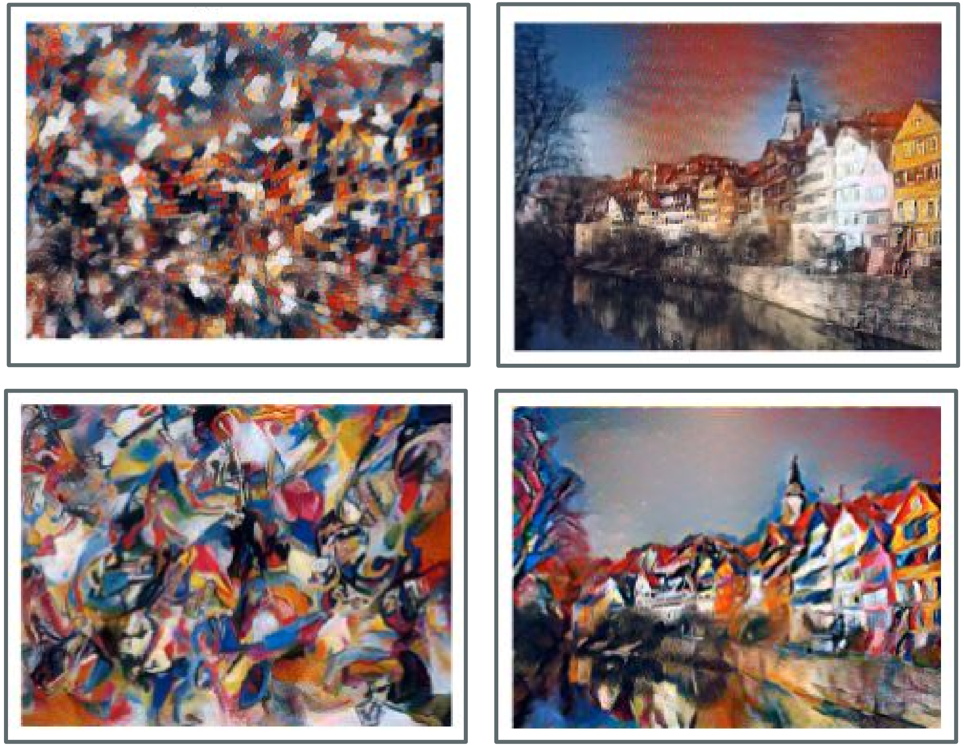
Content/Style Representations

10^{-5} 10^{-2}

Conv1_1

Conv5_1



Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Content/Style Representations

Conv1_1

10^{-5}

10^{-2}

- Content represented in lower layers

Gatys, Leon, et al. "A Neural Algorithm of Artistic Style." arXiv (2015).

Content/Style Representations

Conv5_1

10^{-5}

10^{-2}

- Style represented in feature space
  - local arrangements, textural information

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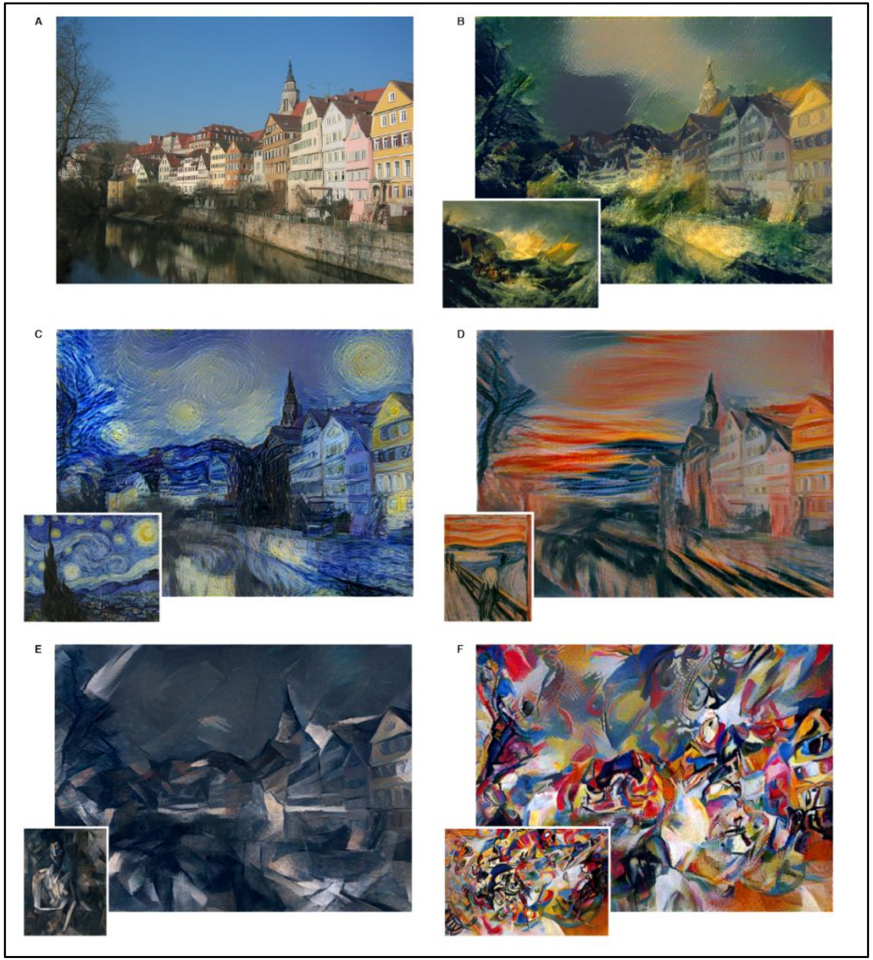
Conclusions

- Learn best pairing between **content** and **style**
  - (Mostly) separable



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