

Neural Style Transfer

Suleyman Demirel University

CSS634: Deep Learning

PhD Abay Nussipbekov

Neural Style Transfer Cost Function



Content C

Style S



Generated image G

$$J(G) = \alpha J_{content}(C, G) + \beta J_{style}(S, G)$$

[Gatys et al., 2015. A neural algorithm of artistic style. Images on slide generated by Justin Johnson]

Find the generated image G

1. Initiate G randomly

$G: 100 \times 100 \times 3$

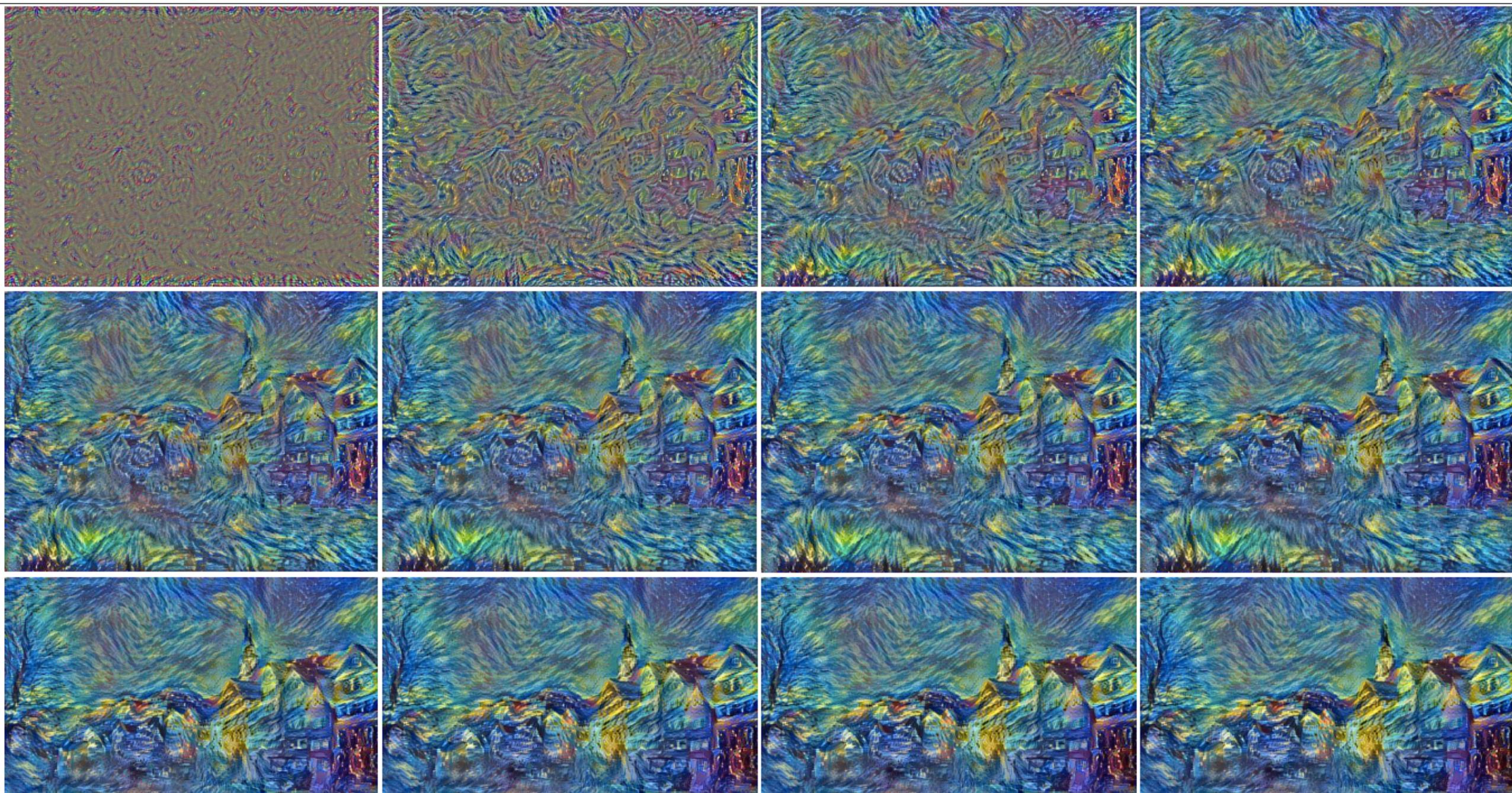


2. Use gradient descent to minimize $J(G)$

$$G := G - \frac{\partial}{\partial G} J(G)$$



[Gatys et al., 2015. A neural algorithm of artistic style]



Content Cost Function

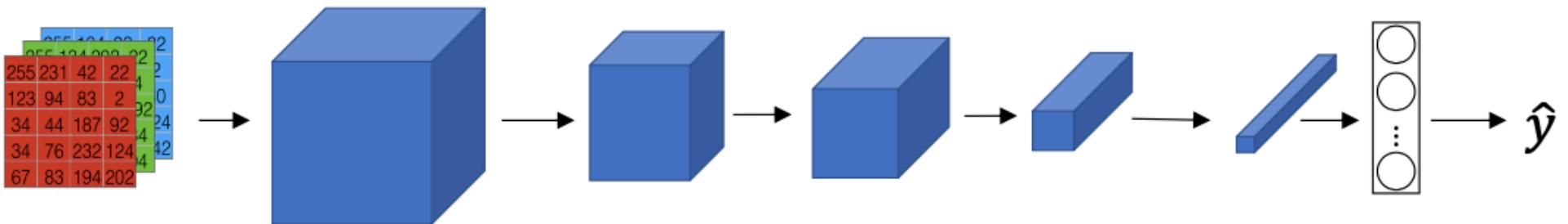
$$J(G) = \alpha J_{content}(C, G) + \beta J_{style}(S, G)$$

- Say you use hidden layer l to compute content cost.
- Use pre-trained ConvNet. (E.g., VGG network)
- Let $a^{[l]}(C)$ and $a^{[l]}(G)$ be the activation of layer l on the images
- If $a^{[l]}(C)$ and $a^{[l]}(G)$ are similar, both images have similar content

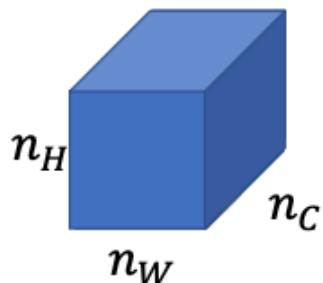
$$J_{content}(C, G) = \frac{1}{2} \|a^{[l]}(c) - a^{[l]}(g)\|^2$$

[Gatys et al., 2015. A neural algorithm of artistic style]

Meaning of the "Style" of an Image



Say you are using layer l 's activation to measure “style.”
Define style as correlation between activations across channels.

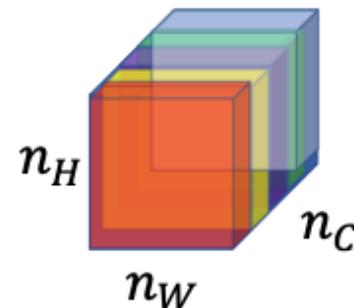


How correlated are the activations
across different channels?

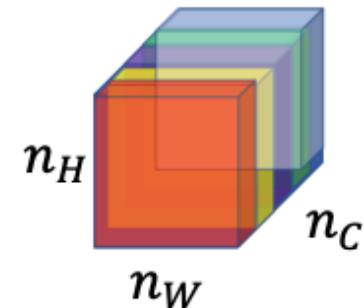
[Gatys et al., 2015. A neural algorithm of artistic style]

Intuition on Style of an Image

Style image



Generated Image



[Gatys et al., 2015. A neural algorithm of artistic style]

Style Matrix

Let $a_{i,j,k}^{[l]}$ = activation at (i,j,k) . $G^{[l]}$ is $n_c^{[l]} \times n_c^{[l]}$

$$G_{kk'}^{[l](S)} = \sum_i^{n_H^{[l]}} \sum_j^{n_W^{[l]}} a_{ijk}^{[l](S)} a_{ijk'}^{[l](S)}$$

$$G_{kk'}^{[l](G)} = \sum_i^{n_H^{[l]}} \sum_j^{n_W^{[l]}} a_{ijk}^{[l](G)} a_{ijk'}^{[l](G)}$$

$$J_{style}^{[l]}(S, G) = \frac{1}{2n_W^{[l]} n_H^{[l]} n_C^{[l]}} \|G^{[l](S)} - G^{[l](G)}\|^2 = \frac{1}{2n_W^{[l]} n_H^{[l]} n_C^{[l]}} \sum_k \sum_{k'} (G_{kk'}^{[l](S)} - G_{kk'}^{[l](G)})^2$$

[Gatys et al., 2015. A neural algorithm of artistic style]

Style Cost Function

$$J_{style}^{[l]}(S, G) = \frac{1}{\left(2n_H^{[l]}n_W^{[l]}n_C^{[l]}\right)^2} \sum_k \sum_{k'} (G_{kk'}^{[l](S)} - G_{kk'}^{[l](G)})$$

$$J_{style}(S, G) = \sum_l \lambda^{[l]} J_{style}^{[l]}(S, G)$$

$$J(G) = \alpha J_{content}(C, G) + \beta J_{style}(S, G)$$

Gatys et al., 2015. A neural algorithm of artistic style]

Neural Style Transfer

Content Image



+

Style Image



[Starry Night](#) by Van Gogh is in the public domain

=



[This image](#) copyright Justin Johnson, 2015. Reproduced with permission.

Neural Style Transfer

Example outputs from
[my implementation](#)
(in Torch)



Gatys, Ecker, and Bethge, "Image style transfer using convolutional neural networks", CVPR 2016
Figure copyright Justin Johnson, 2015.

Neural Style Transfer

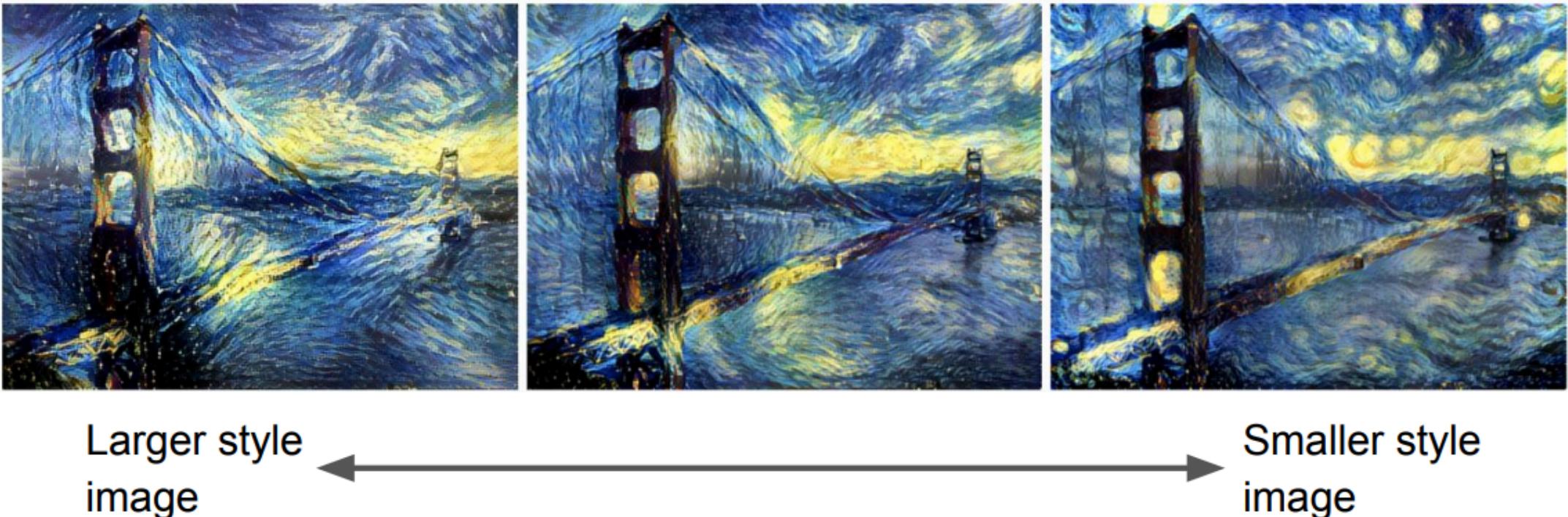


More weight to
content loss

More weight to
style loss

Neural Style Transfer

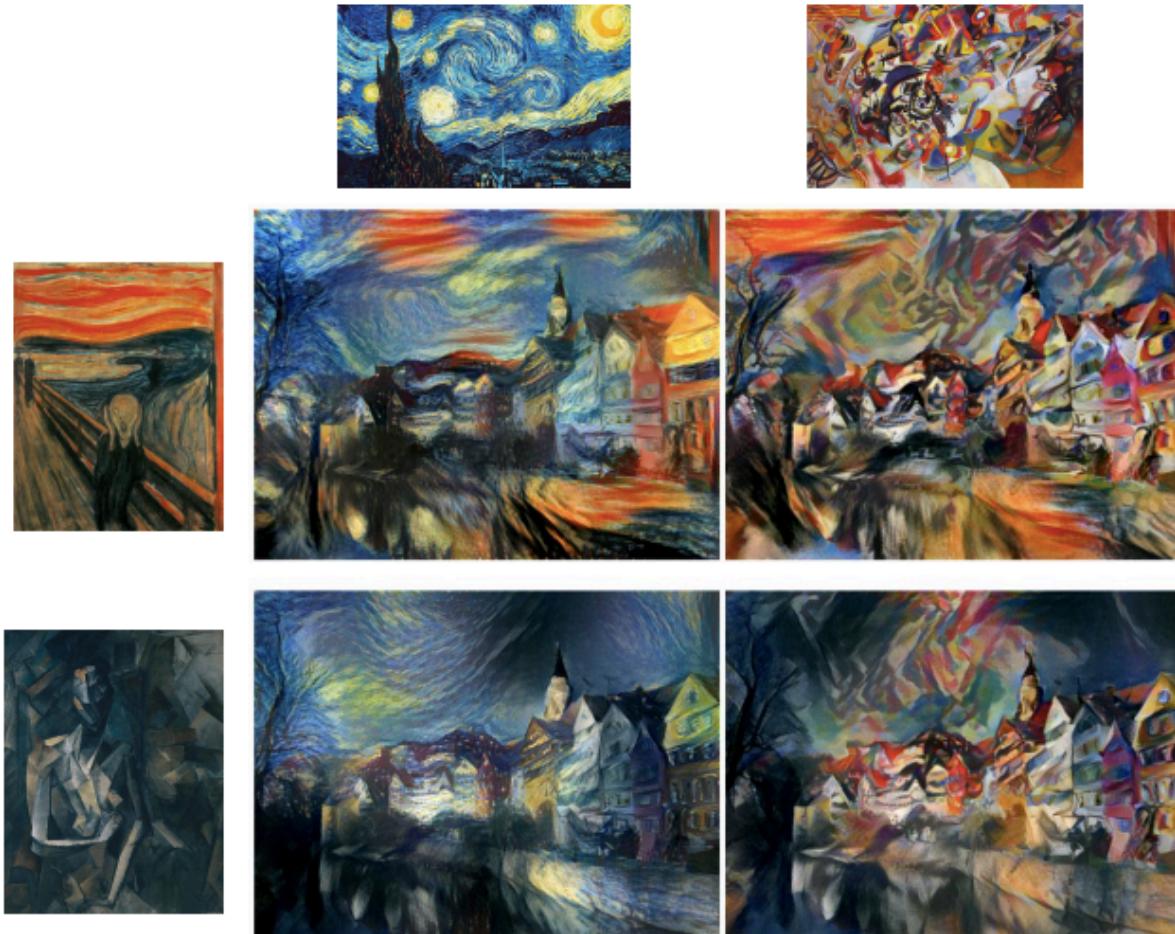
Resizing style image before running style transfer algorithm can transfer different types of features



Gatys, Ecker, and Bethge, "Image style transfer using convolutional neural networks", CVPR 2016
Figure copyright Justin Johnson, 2015.

Neural Style Transfer: Multiple Style Images

Mix style from multiple images by taking a weighted average of Gram matrices



Gatys, Ecker, and Bethge, "Image style transfer using convolutional neural networks", CVPR 2016
Figure copyright Justin Johnson, 2015.

Resources Used

- Deeplearning.ai by Andrew Ng
- CS231n by Fei-Fei Li and Andrej Karpathy