

# Image Style Transfer Using Convolutional Neural Networks

Leon A. Gatys

Centre for Integrative Neuroscience, University of Tübingen, Germany  
Bernstein Center for Computational Neuroscience, Tübingen, Germany  
Graduate School of Neural Information Processing, University of Tübingen, Germany

leon.gatys@bethgelab.org

Alexander S. Ecker

Centre for Integrative Neuroscience, University of Tübingen, Germany  
Bernstein Center for Computational Neuroscience, Tübingen, Germany  
Max Planck Institute for Biological Cybernetics, Tübingen, Germany  
Baylor College of Medicine, Houston, TX, USA

Matthias Bethge

Centre for Integrative Neuroscience, University of Tübingen, Germany  
Bernstein Center for Computational Neuroscience, Tübingen, Germany  
Max Planck Institute for Biological Cybernetics, Tübingen, Germany

## Abstract

*Rendering the semantic content of an image in different styles is a difficult image processing task. Arguably, a major limiting factor for previous approaches has been the lack of image representations that explicitly represent semantic information and, thus, allow to separate image content from style. Here we use image representations derived from Convolutional Neural Networks optimised for object recognition, which make high level image information explicit. We introduce A Neural Algorithm of Artistic Style that can separate and recombine the image content and style of natural images. The algorithm allows us to produce new images of high perceptual quality that combine the content of an arbitrary photograph with the appearance of numerous well-known artworks. Our results provide new insights into the deep image representations learned by Convolutional Neural Networks and demonstrate their potential for high level image synthesis and manipulation.*

## 1. Introduction

Transferring the style from one image onto another can be considered a problem of texture transfer. In texture transfer the goal is to synthesise a texture from a source image while constraining the texture synthesis in order to preserve the semantic content of a target image. For texture synthesis

there exist a large range of powerful non-parametric algorithms that can synthesise photorealistic natural textures by resampling the pixels of a given source texture [7, 30, 8, 20]. Most previous texture transfer algorithms rely on these non-parametric methods for texture synthesis while using different ways to preserve the structure of the target image. For instance, Efros and Freeman introduce a correspondence map that includes features of the target image such as image intensity to constrain the texture synthesis procedure [8]. Hertzman et al. use image analogies to transfer the texture from an already stylised image onto a target image [13]. Ashikhmin focuses on transferring the high-frequency texture information while preserving the coarse scale of the target image [1]. Lee et al. improve this algorithm by additionally informing the texture transfer with edge orientation information [22].

Although these algorithms achieve remarkable results, they all suffer from the same fundamental limitation: they use only low-level image features of the target image to inform the texture transfer. Ideally, however, a style transfer algorithm should be able to extract the semantic image content from the target image (e.g. the objects and the general scenery) and then inform a texture transfer procedure to render the semantic content of the target image in the style of the source image. Therefore, a fundamental prerequisite is to find image representations that independently model variations in the semantic image content and the style in which