ISVC 2021

Deep Tiling: Texture Tile Synthesis Using a Constant Space Deep Learning Approach

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Overview

- Scope
- Introduction
- Related Work
- Deep Tiling
- Experiments
- Conclusions

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Scope

In this paper:

- a novel approach to example-based texture synthesis for creating tiles of arbitrary resolutions that resemble structurally an input texture is proposed
- less memory limited owing to the fact that a new texture tile of small size is synthesized and merged with the existing texture and secondly can easily produce missing parts of a large texture
- a method for removing seams between new synthesized tiles is proposed

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Introduction (1/2)

- Texture synthesis & expansion play a cardinal role in Geographic Information System (GIS) and games
- Structural similarity is the key factor on texture synthesis
- However, many methods that are based on similarity pattern extraction and resemblance are aiming to doubling the size of an input texture → no scalability because of memory limitations on GPUS
- Deep learning has made many steps forward on texture synthesis
  - Limited: no capability to create smaller or arbitrary resolution textures & memory restrictions
- Solution: Tiling

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Introduction (2/2)

Our method:

- is capable of generating new tiles that match structurally and have the same morphology with the original input texture
- utilizes a space invariant deep neural network to produce a new tile that can be used to expand the original texture
- builds a new texture of arbitrary shape and size (tile by tile) by artificially synthesizing tiles in any direction by using constant memory.

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Related Work

- Gatys, L.A., Ecker, A.S., Bethge, M.: Texture synthesis using convolutional neural networks. In: Proceedings of the 28th International Conference on Neural Information Processing Systems
  - **example-based method** employing 2 instances of a **CNN trying to optimize mean square displacement of feature representation across their layer**
- Zhou, Y., Zhu, Z., Bai, X., Lischinski, D., Cohen-Or, D., Huang, H.: Non-stationary texture synthesis by adversarial expansion. ACM Trans. Graph
  - **GAN** - **correlate image features** to produce a new synthesized **high resolution texture map through this process: generator produces 2s × 2s from s x s smaller input texture's pieces** using a loss function consisted of adversarial loss, loss with original sub-texture and style loss
- Frühstück, A., Alhashim, I., Wonka, P.: Tilegan: synthesis of large-scale non-homogeneous textures. ACM Transactions on Graphics
  - **homogenizing texture tiles outputs of GANs** trained on lower resolution textures to produce a higher one with no seam artifacts by **using Markov Random Fields (MRF)**

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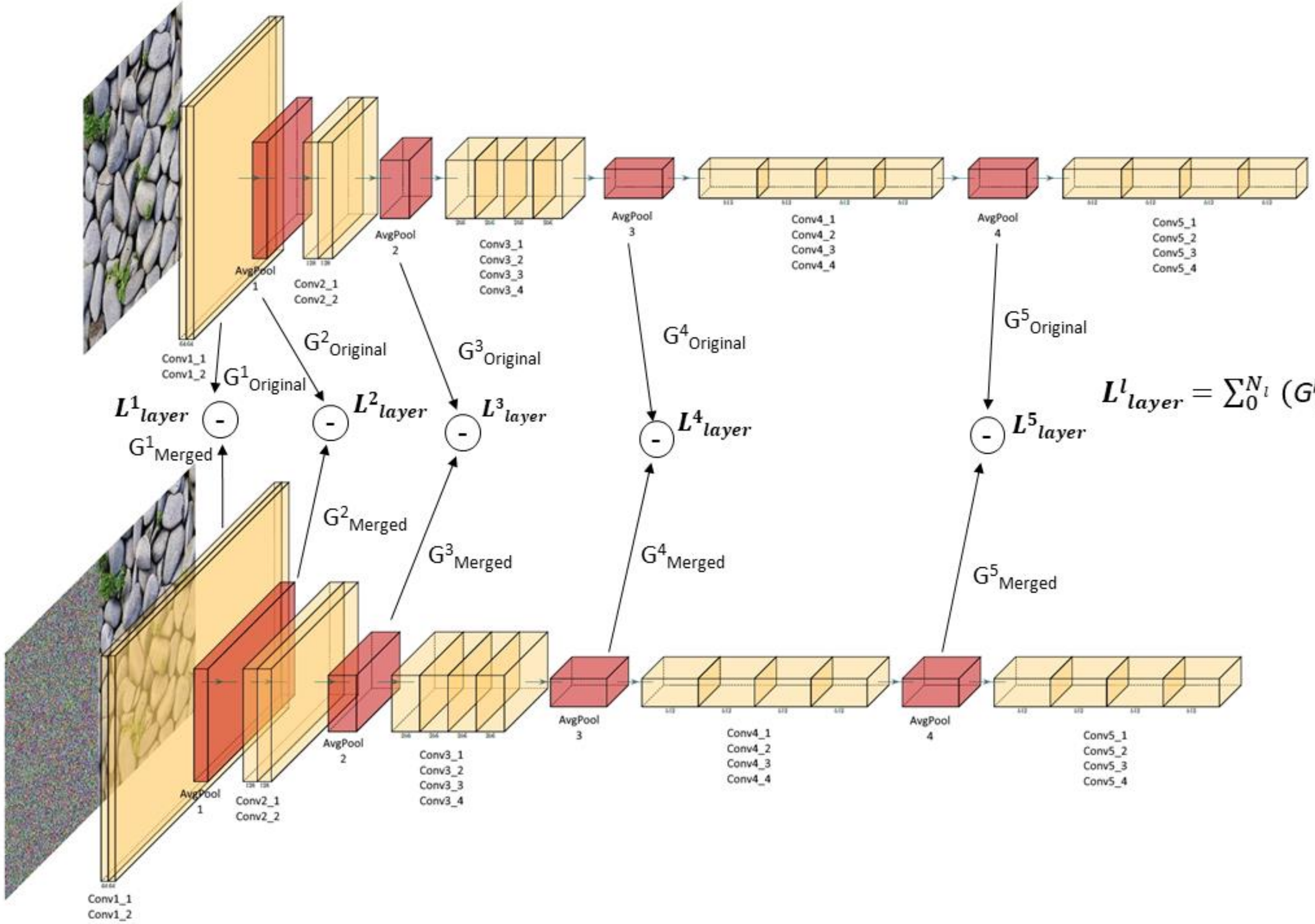
Deep Tiling (1/4)



$$L^l_{layer} = \sum_0^{N_l} (G^l_{Origina} - G^l_{Merged})^2$$

VGG19 instance A

VGG19 instance B

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Deep Tiling (2/4)

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- We follow Gatys's idea and we base our new method to one observation: by the use of Gram Matrices inputs are not mandatory to have equal size (dot product of filters of pre-fixed size not inputs' one)
- To capture correlations among network layers we extract their feature space representation $\boldsymbol{F^l_{li}}$ of a general feature map $\boldsymbol{F^l} \in \boldsymbol{R^{n_f \times vs_f}}$, where $\boldsymbol{l}$ is a layer having $\boldsymbol{n_f}$ filters of size $\boldsymbol{vs_f}$ reshaped into one dimensional vectors
  - Achieved by use of Gram: $\boldsymbol{G^l_{rc}} = \sum_i \boldsymbol{F^l_{ki}}\, \boldsymbol{F^l_{li}}$
- Loss: $\boldsymbol{L_{total}}(\boldsymbol{I_{original}}, \boldsymbol{I_{merged}}) = \sum_{l=1}^{N^L} \frac{w^l}{4{n^l_f}^2 {vs^l_f}^2} \sum (\boldsymbol{G^l_{original}} - \boldsymbol{G^l_{merged}})^2$, where

$\boldsymbol{I_{original}}$ is the original texture and $\boldsymbol{I_{merged}}$ is a white noise texture merged with the original one having been forwarded to our system

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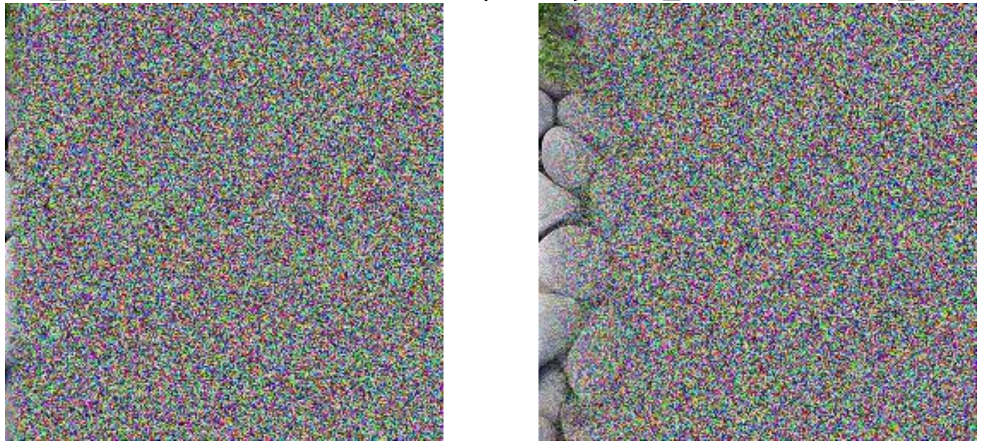
Deep Tiling (3/4)

- In some texture input cases the output of our method produces some noise in the boundaries of the original and deep generated tile
- **Solution → Mirroring with attenuation**
- **Seam Removal:** every pixel for the $Merged$ part of our model is computed as:

$$\boldsymbol{Noise(i,j) = w_1 Original(i, width - j - i) + w_2 RandomColor},$$

where $\boldsymbol{w_1} = \boldsymbol{e^{-\alpha j}}$ with $\boldsymbol{\alpha} \in (\mathbf{0}, \mathbf{1})$, $\boldsymbol{w_2} = \mathbf{1} - \boldsymbol{w_1}$, $\boldsymbol{i}$ and $\boldsymbol{j}$ rows and columns according

α=0.25



α=0.05

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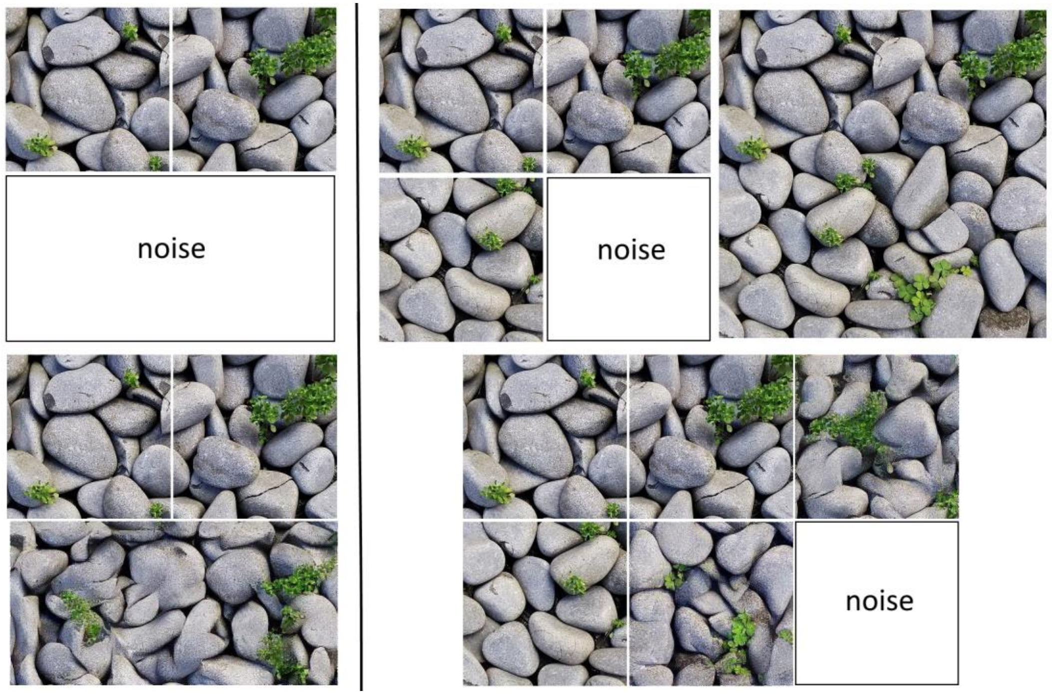
Deep Tiling (4/4)

- **Seam Removal optimal α:**

$$\alpha = -\frac{50 \ \ln(0.5)}{c}$$

where $c \times r$ is the resolution of the input texture and optimal visual result is derived by setting as target an attenuation of 50% (i.e. $w_1 = 0.5$) of the original mirrored image when we reach the 2% of the total number of columns (i.e. $j = c/50$)



- **Tiling process:**
  - Left: Simple Right & then Down Tiling
  - Right: The second method is capable of keeping constant the amount of memory needed to expand a texture to any direction

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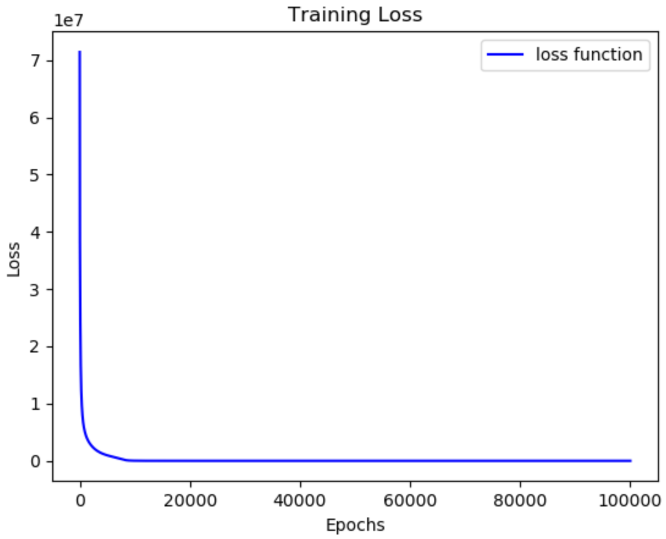
Experiments (1/2)



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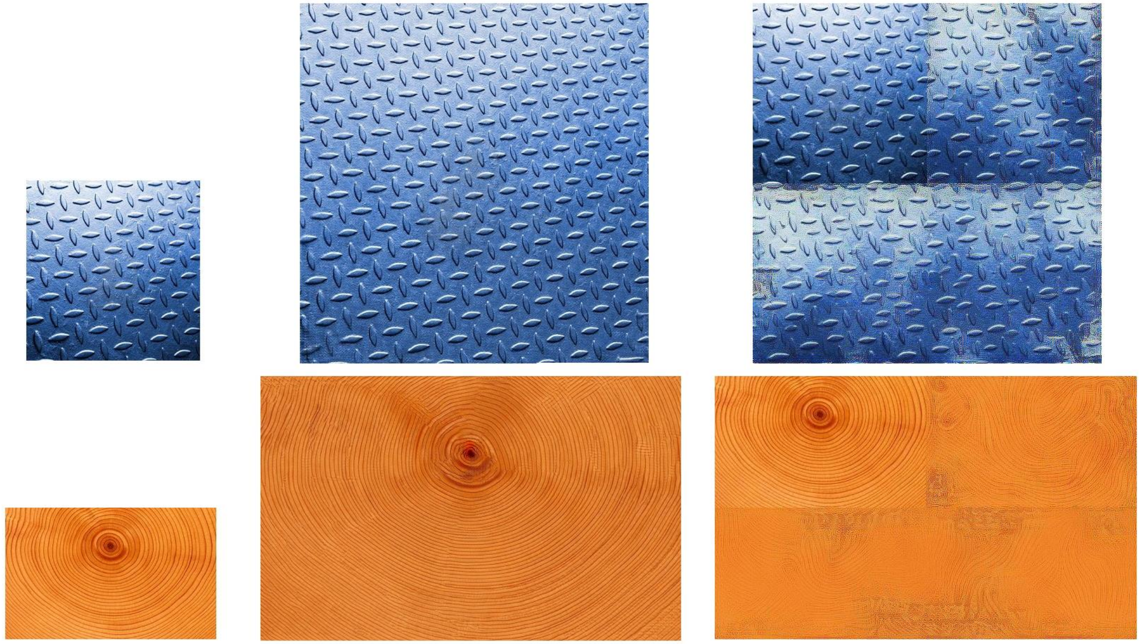
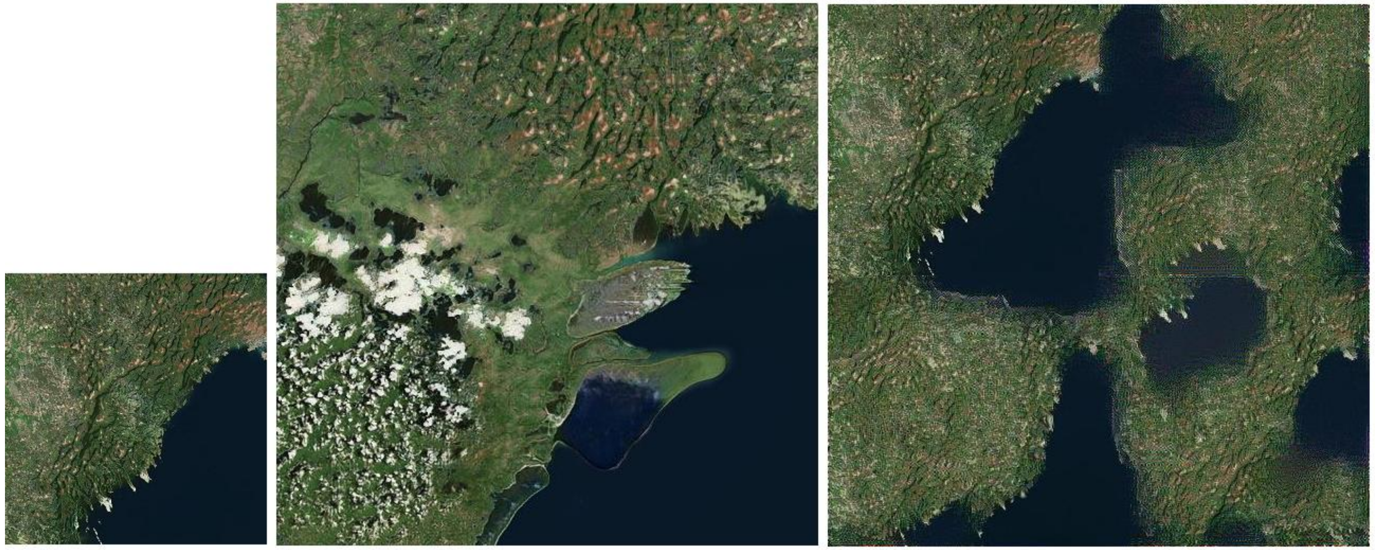
Experiments (2/2)

- **Informal comparison** with state-of-the-art methods



Non-stationary texture synthesis
by adversarial expansion



Tilegan: synthesis of large-scale
non-homogeneous textures

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Conclusions

- An innovative tiling synthesis method is proposed that is capable of producing new texture tiles in any direction and there are techniques to keep memory consumption constant
- Introduction of Seam Removal to texture synthesis
- A limitation of our approach is that noise is passed on from one tile to another
- Targeting on creating tiles with style transfer for a non homogenous style & pattern texture synthesis

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Thank you for your attention

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