

Handwriting Generation

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Motivation

Generate handwriting without a pen

- Help people when writing is physically impaired
- Produce personalized cards / invitations
- Automatic manipulation of handwriting in movies to match the specific language
- Training data for automatic text recognition



Source: https://commons.wikimedia.org/wiki/File:Broken_right_hand_in_orange_cast.jpg (CC-BY-SA) | <https://www.pinterest.ru/pin/499125571171917604/>

Outline

Word Generation

Method Overview

SmartPatch

Full-Line Generation

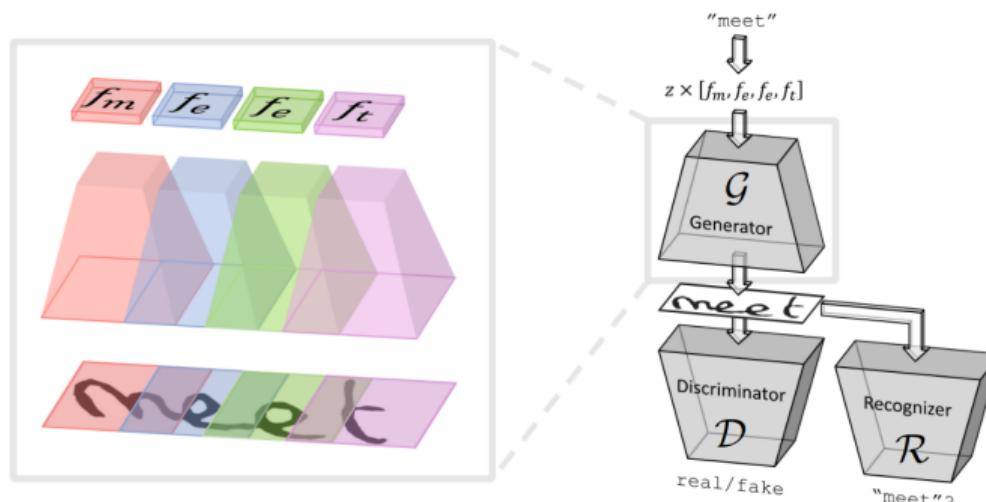
Summary & Outlook

Word Generation



Method Overview

ScrabbleGAN - Synthesizing Handwriting



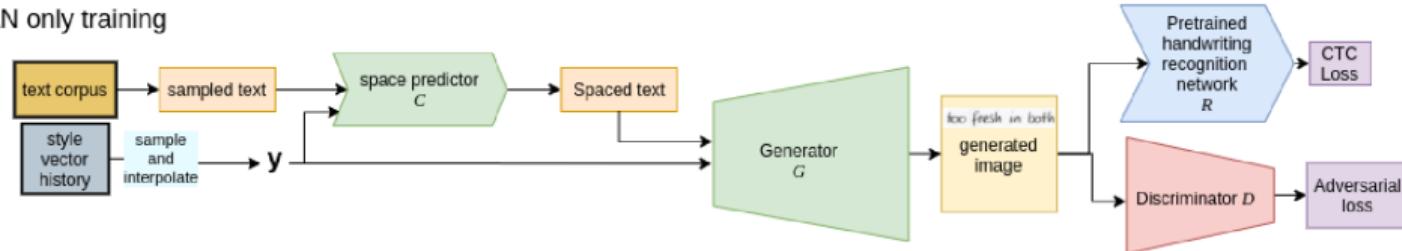
Sharon Fogel et al. "ScrabbleGAN: Semi-Supervised Varying Length Handwritten Text Generation". In: *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*. June 2020

ScrabbleGAN

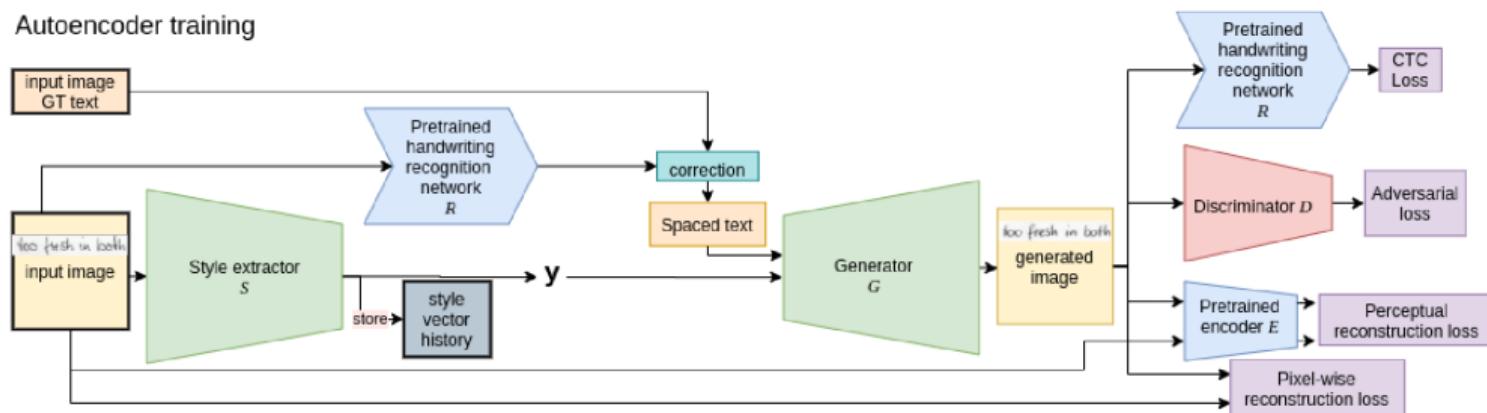
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Davis et al.

GAN only training



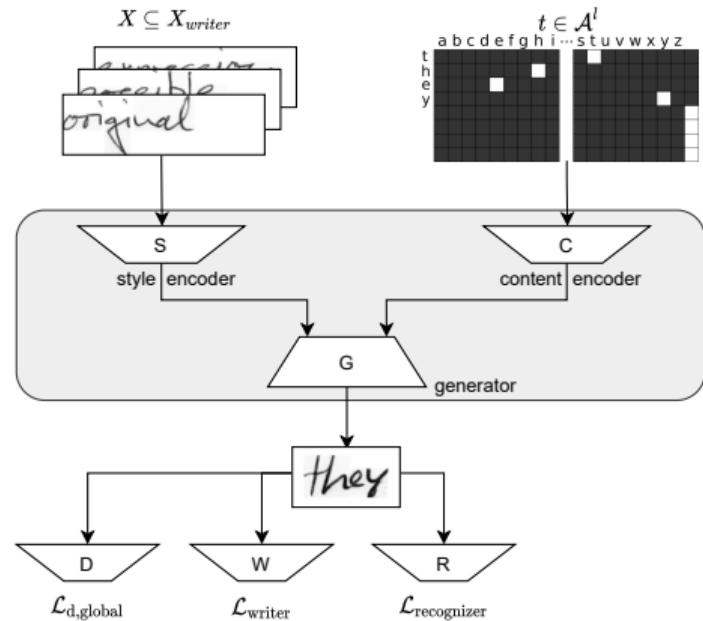
Autoencoder training



ScrabbleGAN vs. Davis et al.

Supercalifragilisticexpialidocious

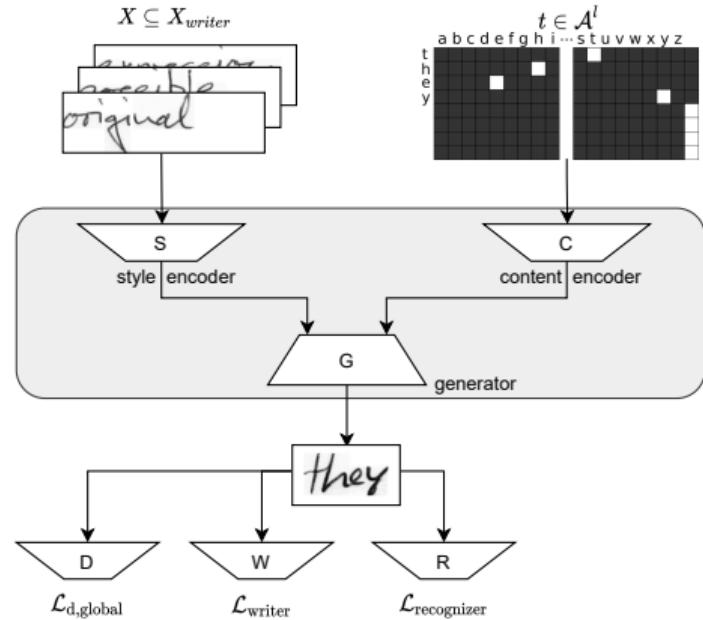
GANwriting - Handwriting Imitation



- Generator input: clear-text and word-images

Lei Kang et al. "GANwriting: Content-Conditioned Generation of Styled Handwritten Word Images". In: *Computer Vision – ECCV 2020*. Ed. by Andrea Vedaldi et al. Cham: Springer International Publishing, 2020, pp. 273–289

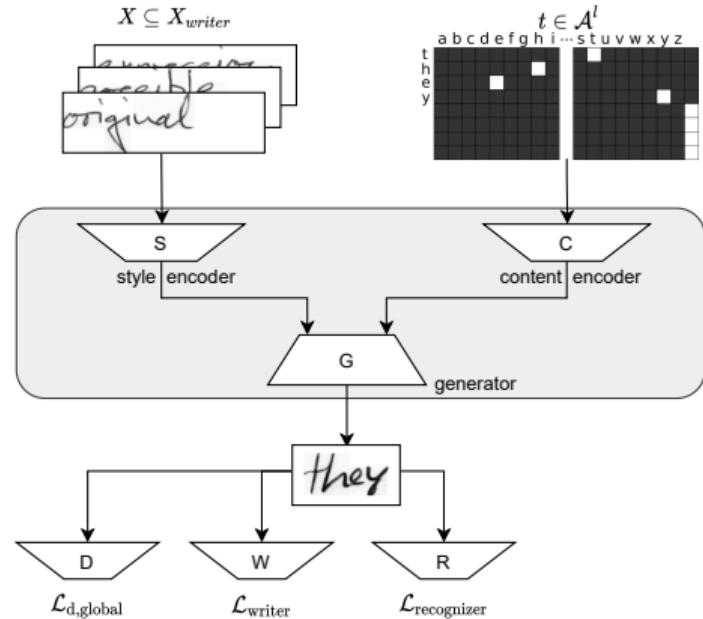
GANwriting - Handwriting Imitation



- Generator input: clear-text and word-images
- Generator output: image with content of the clear-text and style of word-samples

Lei Kang et al. "GANwriting: Content-Conditioned Generation of Styled Handwritten Word Images". In: *Computer Vision – ECCV 2020*. Ed. by Andrea Vedaldi et al. Cham: Springer International Publishing, 2020, pp. 273–289

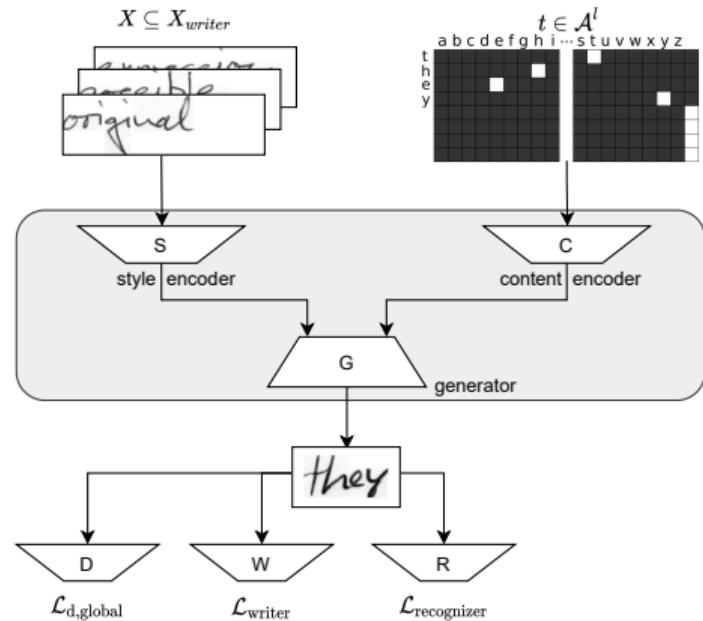
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- Generator input: clear-text and word-images
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- GAN-discriminator

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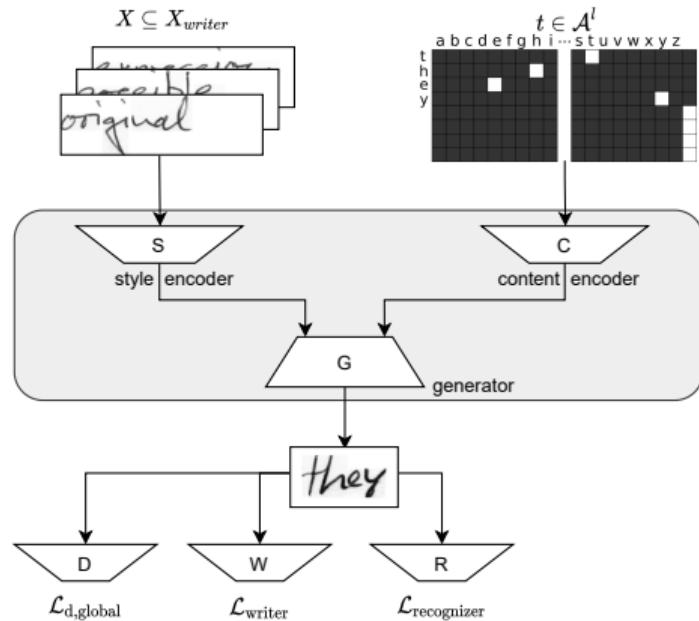
GANwriting - Handwriting Imitation



- Generator input: clear-text and word-images
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- GAN-discriminator
- HTR-model for content loss

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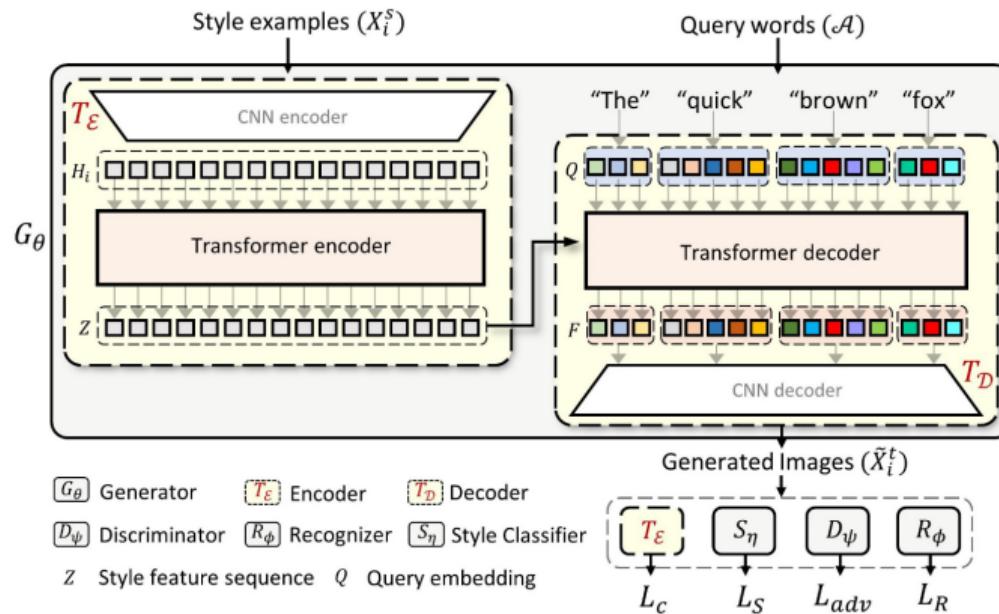
GANwriting - Handwriting Imitation



- Generator input: clear-text and word-images
- Generator output: image with content of the clear-text and style of word-samples
- GAN-discriminator
- HTR-model for content loss
- Writer-identification for style loss

Lei Kang et al. "GANwriting: Content-Conditioned Generation of Styled Handwritten Word Images". In: *Computer Vision – ECCV 2020*. Ed. by Andrea Vedaldi et al. Cham: Springer International Publishing, 2020, pp. 273–289

Handwriting Transformer



Ankan Kumar Bhunia et al. "Handwriting Transformers". In: *Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV)*. Oct. 2021, pp. 1086–1094

Handwriting Transformer (HWT) vs. GANwriting vs. Davis et al.

Style examples	HWT (Ours)	GANwriting	Davis et al.
I good neighbour & those Africans who will can since he has in heart & not not others &	No two people can write precisely the same way just like no two people can have the same fingerprints	No two people can write precisely the same way just like no two people can have the same finger?	No two people can write precisely the same way, just like no two people can have the same fingerprints
The process has been too slow for Herr Strauss and last month he attacked Britain for being an	No two people can write precisely the same way just like no two people can have the same fingerprints	No two people can write precisely the same way just like no two people can have the same finger?	No two people can write precisely the same way, just like no two people can have the same fingerprints
These HWT loud cries of 'shame' from all parts of the Conservative side Mr. Sell appeared to be in the thoughts he said, if the socialist Union would be prepared to make an agreement for a zone of	No two people can write precisely the same way just like no two people can have the same fingerprints	No two people can write precisely the same way just like no two people can have the same finger?	No two people can write precisely the same way, just like no two people can have the same fingerprints
Mr. Macleod went off with the conference at Lancaster House despite the crisis which had blown by the end of the month he still delighted in Wadles he told Gloucester that he enjoyed it all	No two people can write precisely the same way just like no two people can have the same fingerprints	No two people can write precisely the same way just like no two people can have the same finger?	No two people can write precisely the same way, just like no two people can have the same fingerprints
	No two people can write precisely the same way just like no two people can have the same fingerprints	No two people can write precisely the same way just like no two people can have the same finger?	No two people can write precisely the same way, just like no two people can have the same fingerprints

Defects of GANwriting



Figure: Frequently appearing artifacts in the outputs of GANwriting.

Defects of GANwriting

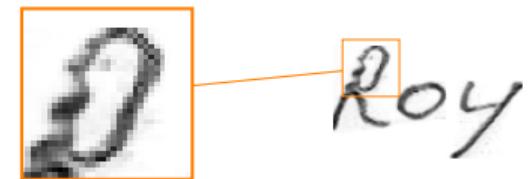


Figure: Frequently appearing artifacts in the outputs of GANwriting.

- “stepping” artifacts

Defects of GANwriting

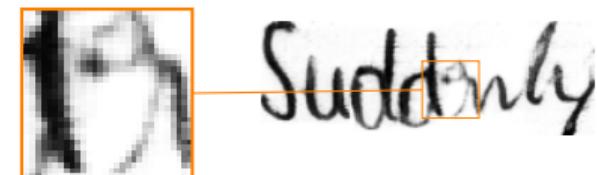


Figure: Frequently appearing artifacts in the outputs of GANwriting.

- “stepping” artifacts
- thin lines

Defects of GANwriting



Figure: Frequently appearing artifacts in the outputs of GANwriting.

- “stepping” artifacts
- thin lines
- smudged lines

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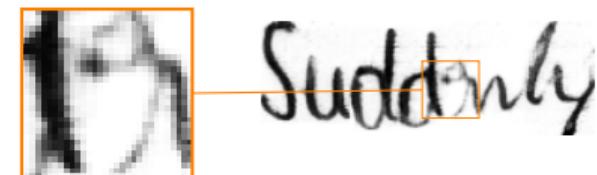
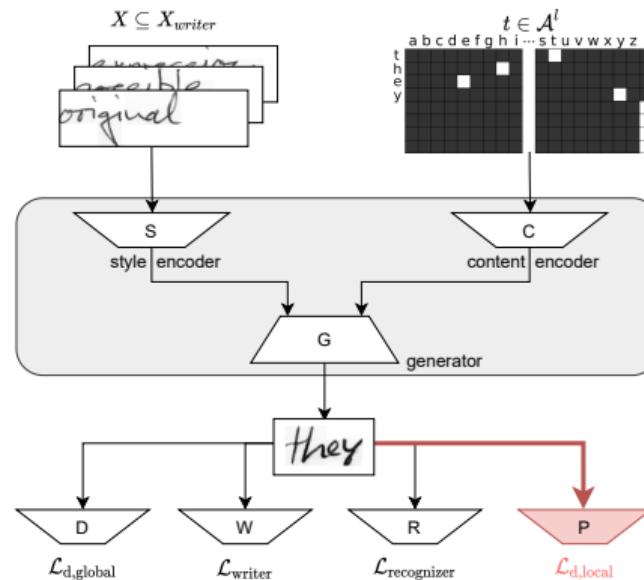


Figure: Frequently appearing artifacts in the outputs of GANwriting.

- “stepping” artifacts
- thin lines
- smudged lines
- unsteady lines

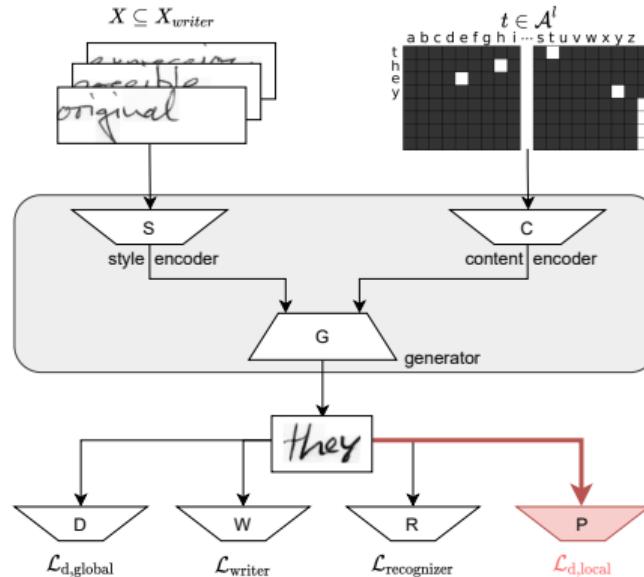
SmartPatch

SmartPatch



Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

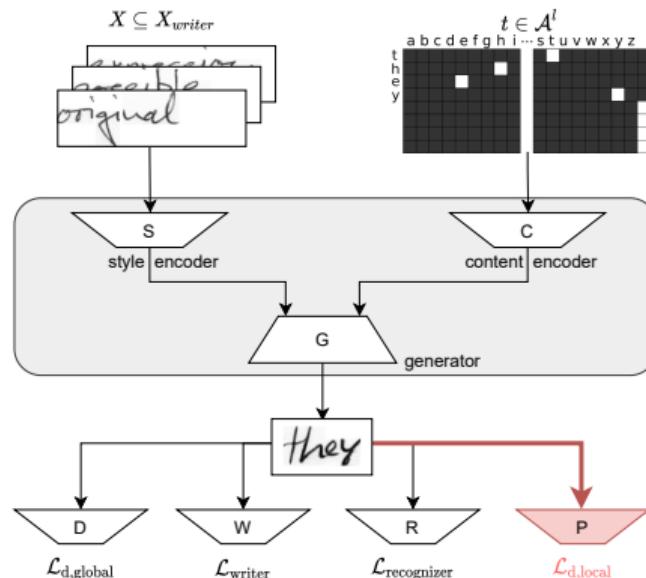
SmartPatch



- Dedicated discriminator for character level

Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

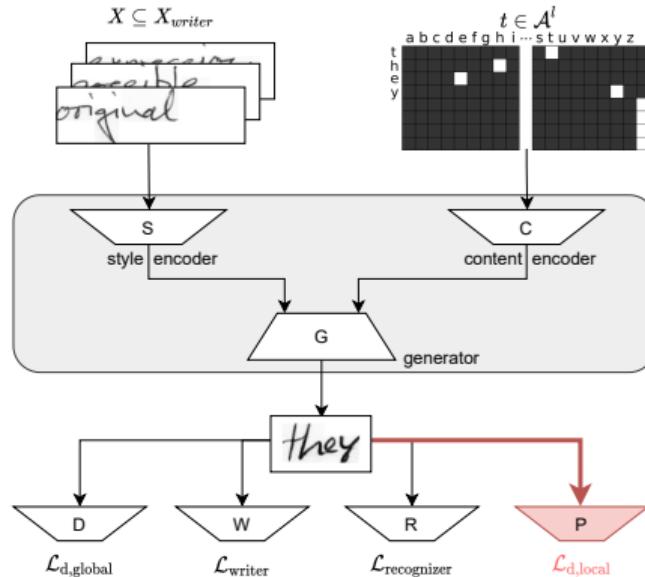
SmartPatch



- Dedicated discriminator for character level
- Rolling patches: 64×64 patches with stride 32

Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

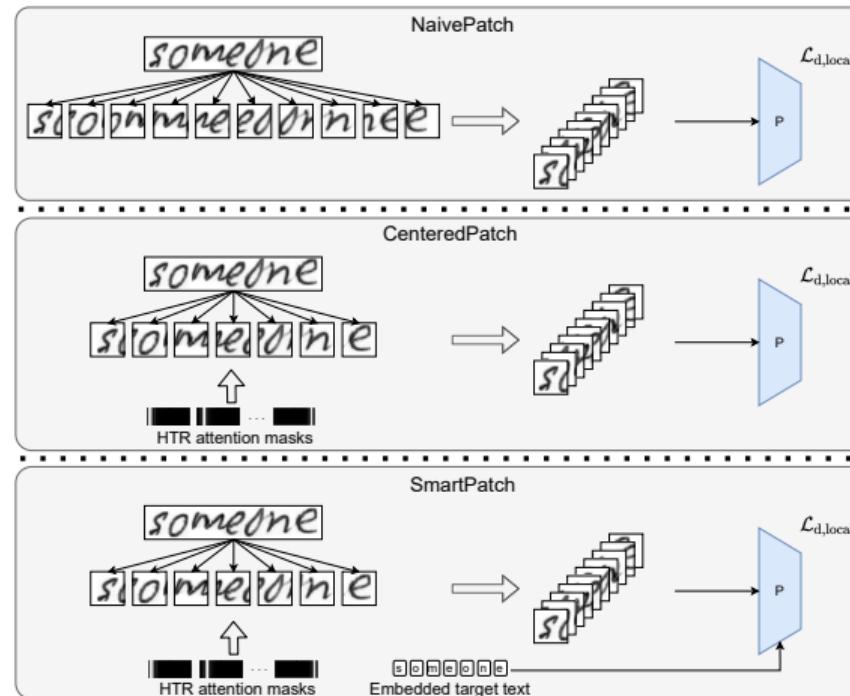
SmartPatch



- Dedicated discriminator for character level
- Rolling patches: 64×64 patches with stride 32
- Discriminator: small pix2pix 70×70 receptive field

Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

SmartPatch - Discriminator Designs

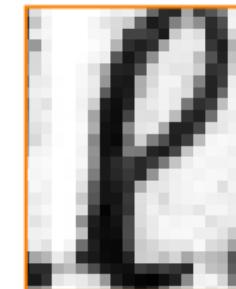
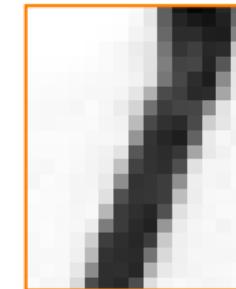
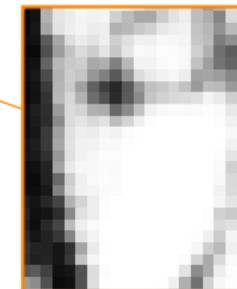
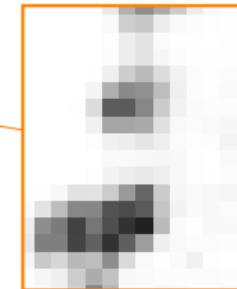


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GANwriting vs. SmartPatch

Dinas

Suddenly

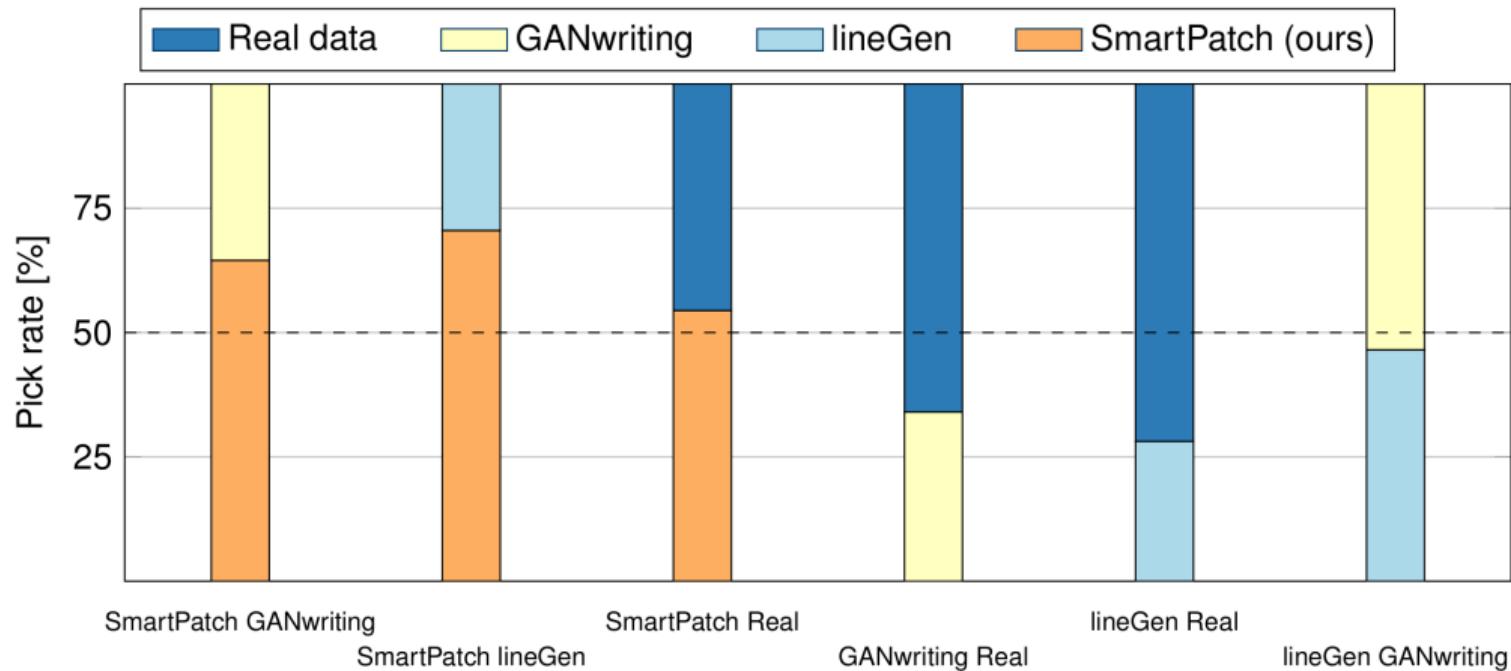


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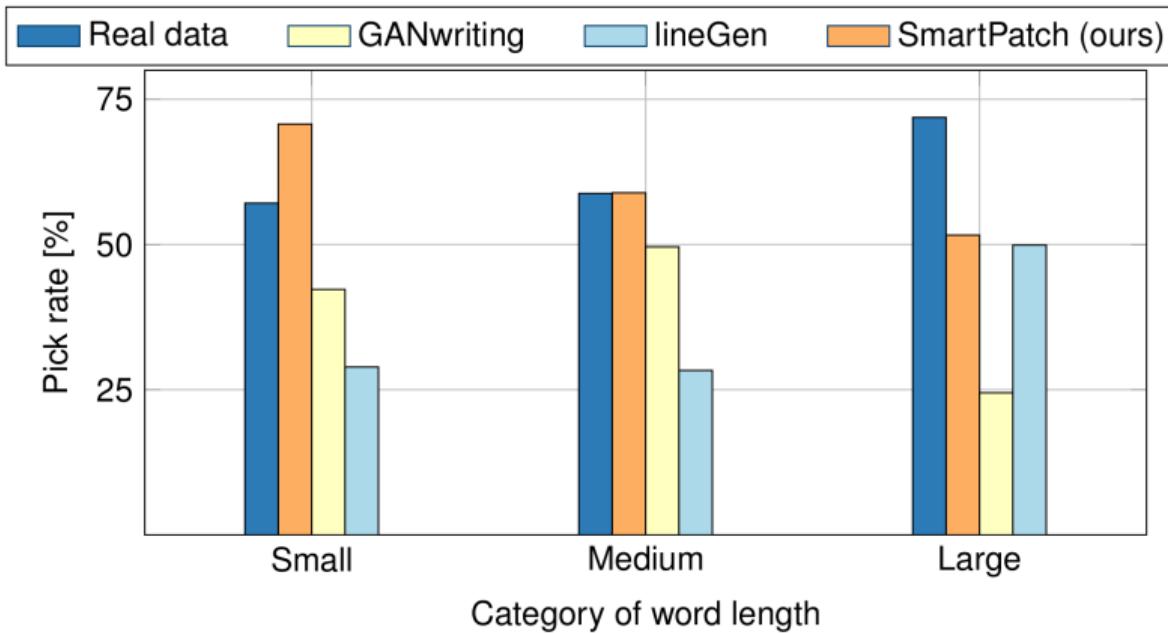
Lei Kang et al. "GANwriting: Content-Conditioned Generation of Styled Handwritten Word Images". In: *Computer Vision – ECCV 2020*. Ed. by Andrea Vedaldi et al. Cham: Springer International Publishing, 2020, pp. 273–289; Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

Results



Alexander Mattick et al. "SmartPatch: Improving Handwritten Word Imitation with Patch Discriminators". In: *Document Analysis and Recognition – ICDAR 2021*. Ed. by Josep Lladós, Daniel Lopresti, and Seiichi Uchida. Cham: Springer International Publishing, 2021, pp. 268–283

Results



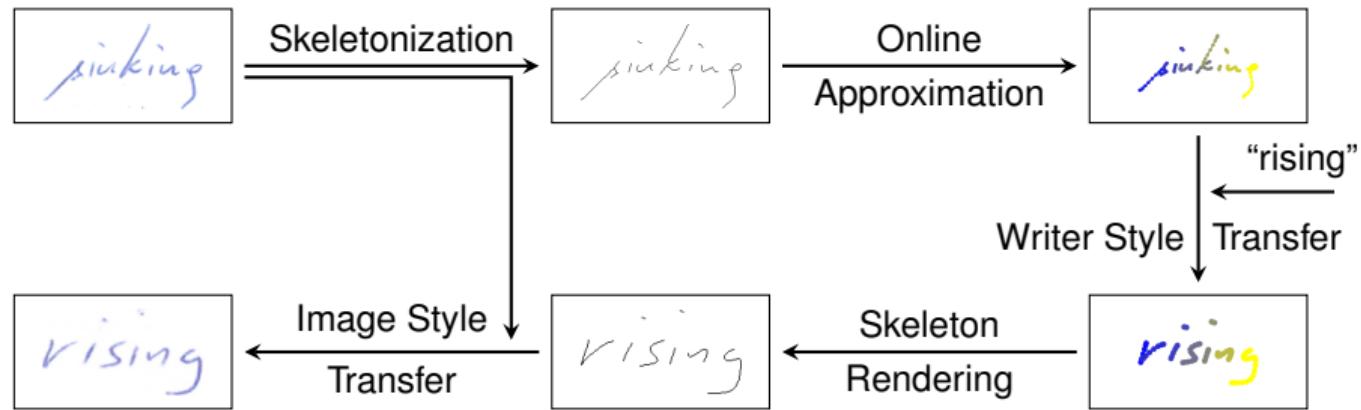
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Full-Line Generation



Spatio-Temporal Handwriting Imitation

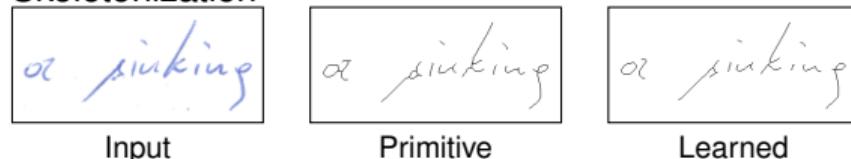
Overview



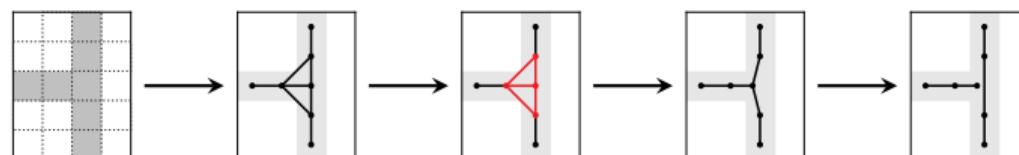
Spatio-Temporal Handwriting Imitation

From Offline to Online Data

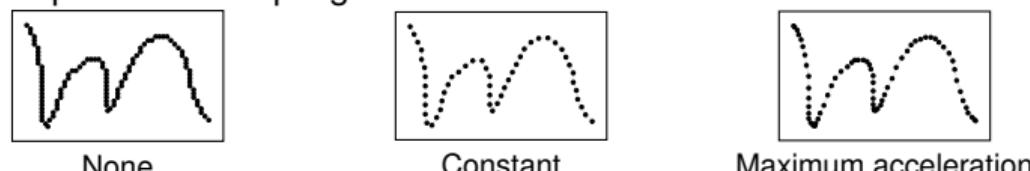
1. Skeletonization



2. Skeletons → strokes



3. Importance sampling



Martin Mayr et al. "Spatio-Temporal Handwriting Imitation". In: *Computer Vision – ECCV 2020 Workshops*. 2020, pp. 528–543

Writer Style Transfer

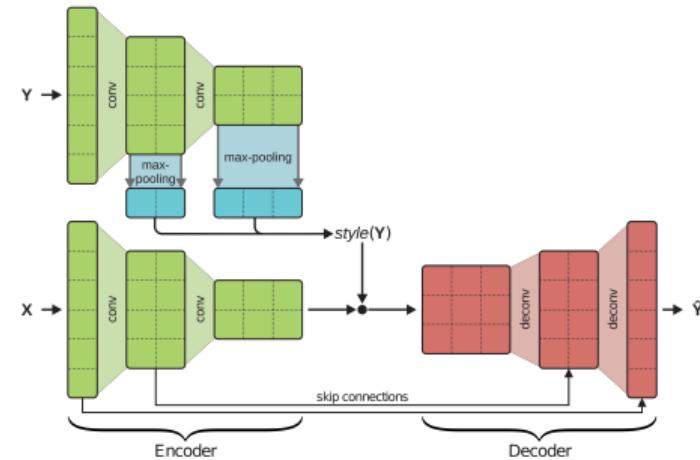
Online Handwriting Synthesis¹

Style Input	Output
spineless!" "You think you could	I am a synthetic sample
Michael Caxton The father	I am a synthetic sample
they get' em. We've been alert	I am a synthetic sample
one for me?" Jaws did so, and	I am a synthetic sample
any better? You know it was! He	I am a synthetic sample
and change the money	I am a synthetic sample

¹ Alex Graves. Generating Sequences With Recurrent Neural Networks. Aug. 2013. arXiv: 1308.0850 [cs.NE].

Image/Pen Style Transfer

- Extract style information of the input image
- Remove spatial information of style
- Add to generated image

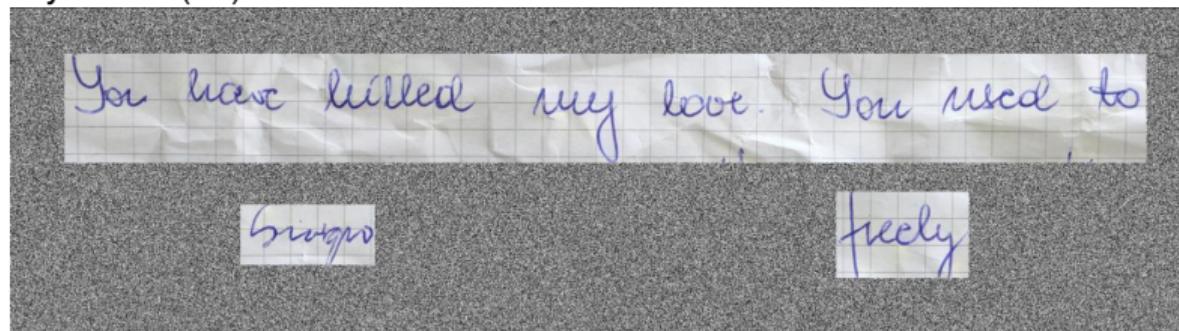


Results – User Study

- Turing task (32): Fake or Real?

straight

- Style task (64):

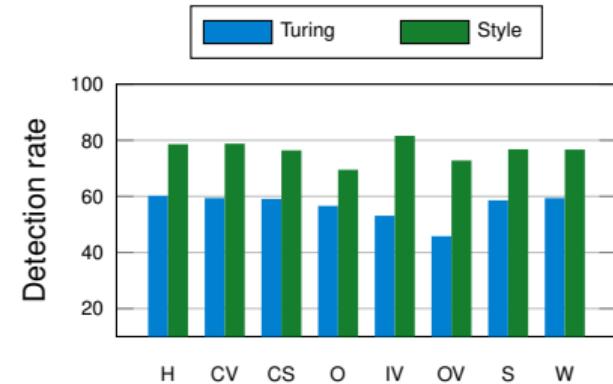


Results – User Study

- 59 participants
- Accuracy Turing task: 58.7 %
- Accuracy Style task: 76.8 %

Results – User Study

- 59 participants
- Accuracy Turing task: 58.7 %
- Accuracy Style task: 76.8 %
- Humanities (H) have best performance (vs. CV, CS, O)
- Out-of-Vocabulary (OV) better imitated than in vocabulary (IV)
- No impact of synthetic background (S vs. W)



Qualitative Results

(a)

Imagine a vast sheet of paper on which straight
straight attention curiosity

(b)

Assembly Higher Varied

(c)

You have killed my love. You used to it was not written by me

(d)

You have killed my love. you used to stir my plants and animals one

(e)

This was not written by me

This was not written by me

Qualitative Results

When we look to the same variety or our older cultivated animals, one of the strikes us, is, that much more form each individuals of any variety in a site

(a)



(b)



(c)

When we look to the individuals of the same variety or sub of our older cultivated plants and animals one of the first points which strikes us is that they generally do

(d)



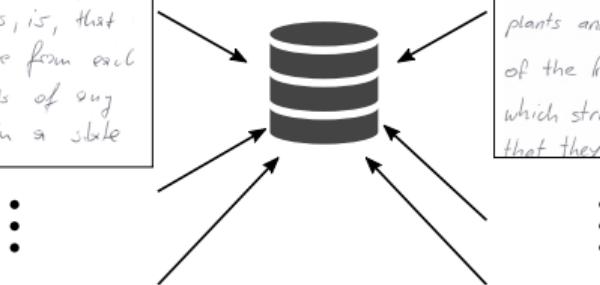
Results – Writer Identification

Real

When we look to the same variety of our older cultivated animals, one of the strikes us, is, that much more from each individuals of any variety in a state

Generated

When we look to the individuals of the same variety or sub of our older cultivated plants and animals one of the first points which strikes us is that they generally do



DB	mAP %	Acc. %
OV	29.66	14.82
IV	37.13	25.92

Source: <https://iconscout.com/icons/database>

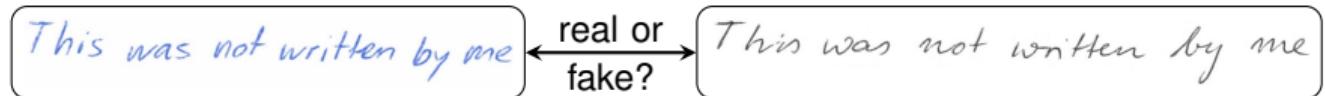
Writer Identification in Generated Images

→ A new layer for writer identification

Summary & Outlook



Summary & Outlook



Summary

- Rapidly improving results on word and line level
- Can be used for improving HTRs

Outlook

- Handwriting imitation of whole images

Questions?

Missed something? Please let us know!

References



References I

- [Bhu+21] Ankan Kumar Bhunia, Salman Khan, Hisham Cholakkal, Rao Muhammad Anwer, Fahad Shahbaz Khan, and Mubarak Shah. "Handwriting Transformers". In: *Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV)*. Oct. 2021, pp. 1086–1094.
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- [Kan+20] Lei Kang, Pau Riba, Yaxing Wang, Marçal Rusiñol, Alicia Fornés, and Mauricio Villegas. “GANwriting: Content-Conditioned Generation of Styled Handwritten Word Images”. In: *Computer Vision – ECCV 2020*. Cham: Springer International Publishing, 2020, pp. 273–289.
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- [May+20] Martin Mayr, Martin Stumpf, Anguelos Nicolaou, Mathias Seuret, Andreas Maier, and Vincent Christlein. “Spatio-Temporal Handwriting Imitation”. In: *Computer Vision – ECCV 2020 Workshops*. 2020, pp. 528–543.