STAN-CT: Standardization and Normalization of CT images for Lung Cancer Patients

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Radiomics

Radiology

Radiomics: Images Are More than Pictures, They Are Data[1] 2016

nature COMMUNICATIONS 2014

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Article | OPEN | Published: 03 June 2014

Decoding tumour phenotype by noninvasive imaging using a quantitative radiomics approach

Hugo J. W. L. Aerts, Emmanuel Rios Velazquez, Ralph T. H. Leijenaar, Chintan Parmar, Patrick Grossmann, Sara Carvalho, Johan Bussink, René Monshouwer, Benjamin Haibe-Kains, Derek Rietveld, Frank Hoebers, Michelle M. Rietberg, C. René Leemans, Andre Dekker, John Quackenbush, Robert J. Gillies & Philippe Lambin

Nature Communications **5**, Article number: 4006 (2014) | Download Citation

he field of medical image analysis has

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2015 Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

CT based radiomic signature CT-based radiomic signature predicts distant metastasis in lung adenocarcinoma

Thibaud P. Coroller[a,c,1,*], Patrick Grossmann[a,1], Ying Hou[a], Emmanuel Rios Velaz Ralph T.H. Leijenaar[c], Gretchen Hermann[a], Philippe Lambin[c], Benjamin Haibe-Ka Raymond H. Mak[a,1], Hugo J.W.L. Aerts[a,b,c,1,*]

For radiomic studies, it is required to integrate a large amount of CT images.

Zhang, S. & Metaxas, D. (2016). Large-Scale medical image analytics: Recent methodologies, applications and Future directions.

Fang, R et al (2016). Computational health informatics in the big data age: a survey. *ACM Computing Surveys (CSUR)*, *49*(1), 12.

CT images are often acquired with different scanners

- CT Scanners differ by the image reconstruction kernels.
- Each scan manufacturer has its own technical advancements.
- Even using the same scanner, image acquisition parameters may vary.
- There is a critical need to standardize scanning protocols.

Pediatric Radiology
October 2014, Volume 44, Supplement 3, pp 440–443 | Cite as

Standardized CT protocols and nomenclature: better, but not yet there

2014

Authors Authors and affiliations

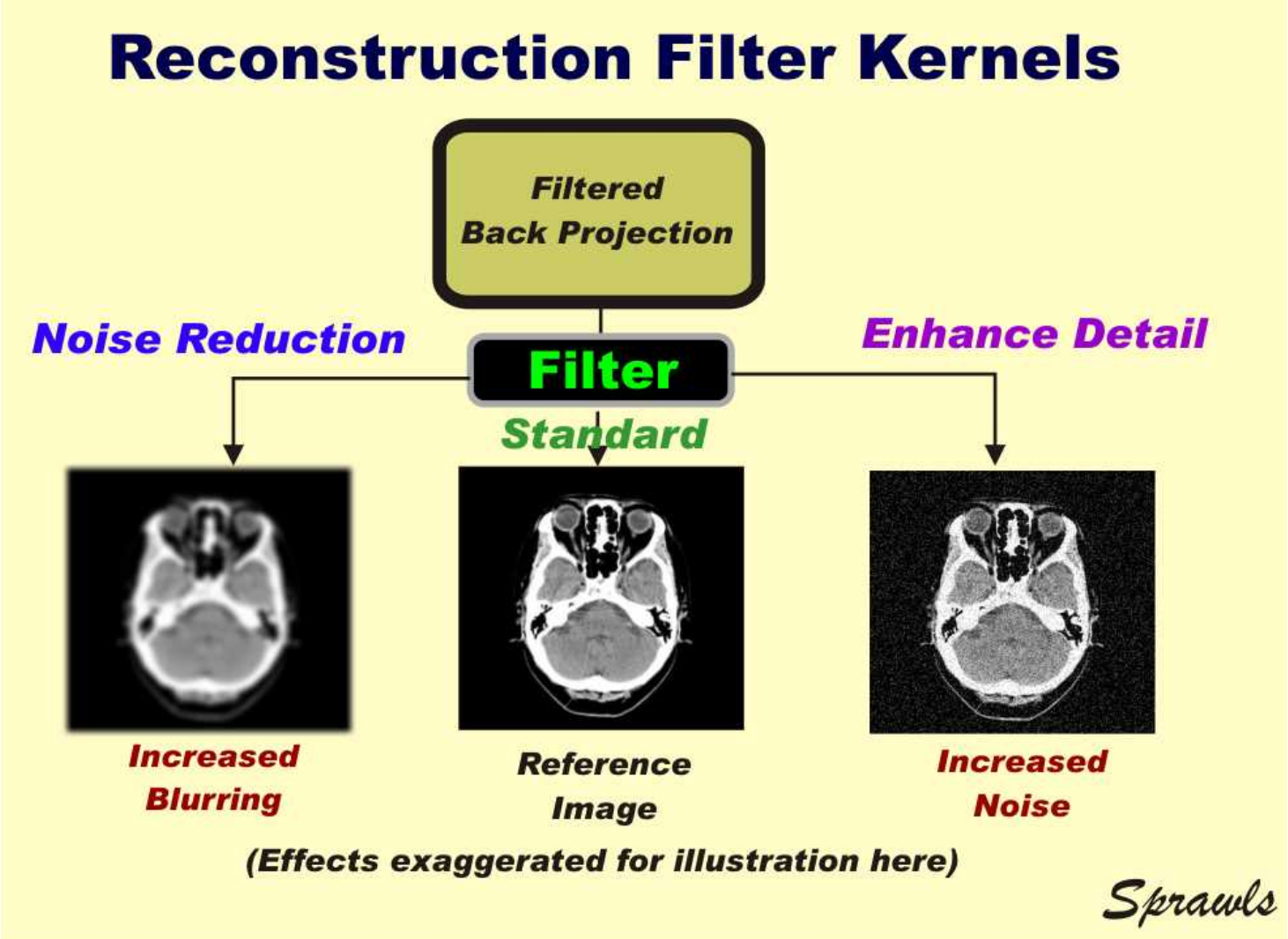
Sarabjeet Singh, Mannudeep K. Kalra

Image Gently ALARA CT summit: How to Use New CT Technologies for Children

First Online: 11 October 2014

CT images are often acquired with different parameters

- Customizing CT acquisition parameters is required to meet *an individual's clinical needs*.
- It facilitates physicians on *disease diagnosis*.



Kak, A. C., & Slaney, M. (2001). *Principles of computerized tomographic imaging*. Society for Industrial and Applied Mathematics.

Standardization and Normalization of CT images for lung cancer patients (STAN-CT)

Problem Definition: given a source CT image *x*, an image synthesis algorithm composes a synthesized image *x'* by specifying a high-level goal that the radiomic features of *x'* are similar to that of the target CT image *y* rather than *x*.

Specific Aims

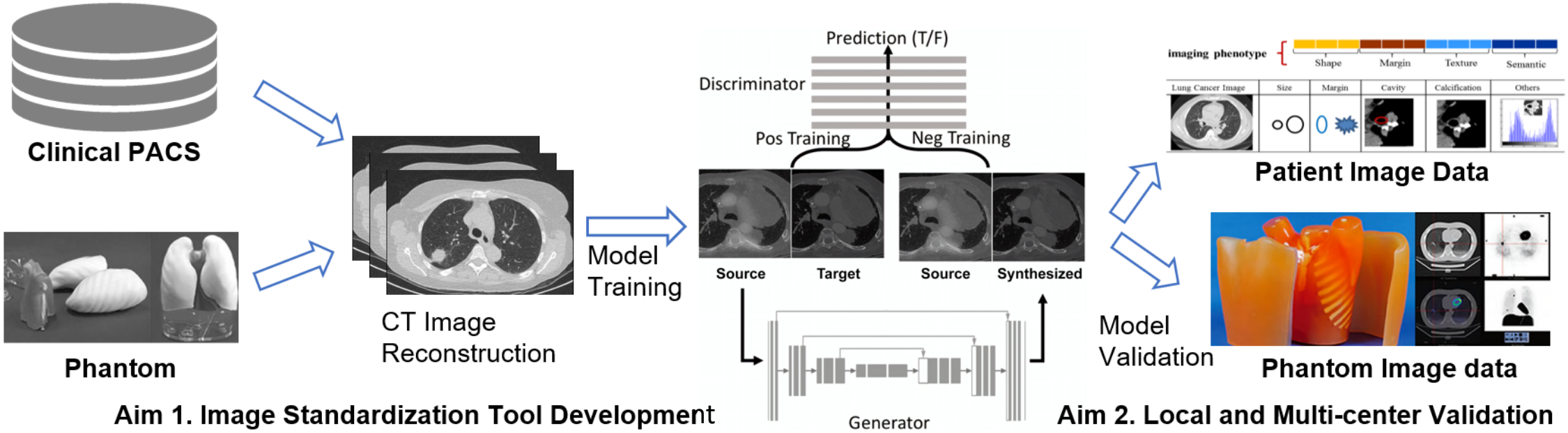
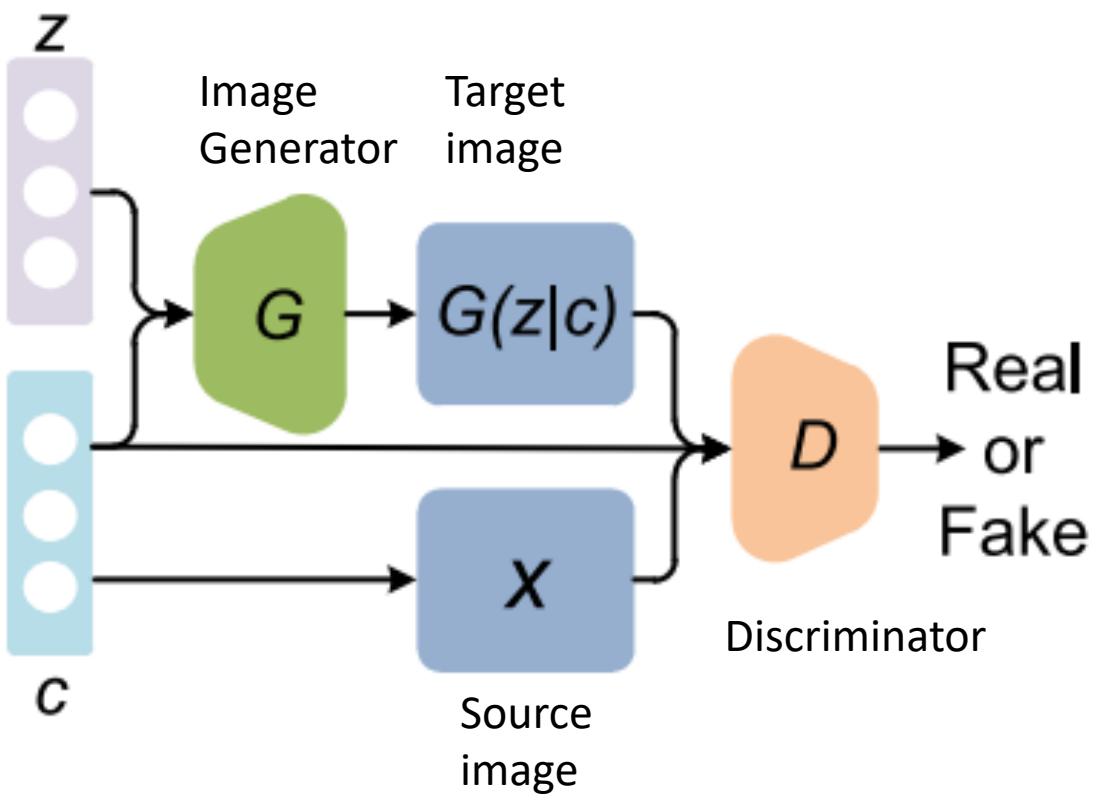
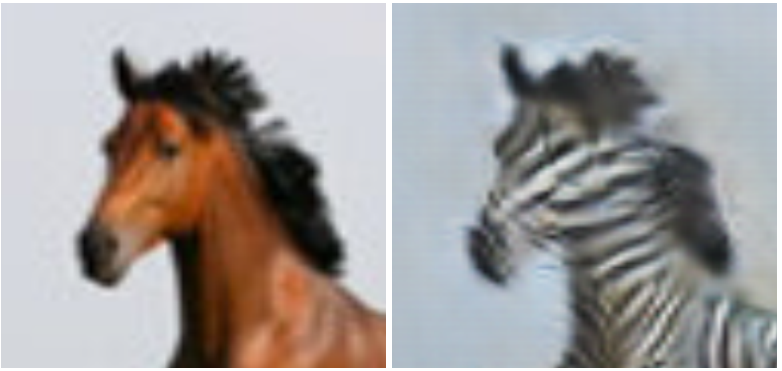


Image-to-image translation with cGAN



Mirza, Mehdi, and Simon Osindero. (2014). Conditional generative adversarial nets. *arXiv preprint arXiv:1411.1784*.
Isola, P. et al (2017). Image-to-image translation with conditional adversarial networks. *CVPR*.

Example: Horse-to-Zebra Transference



- The synthesized result looks good. But if we look into the details, it may not be *trustworthy*.
- For instance, the eye of zebra is missing, the black-white stripes do not look right.

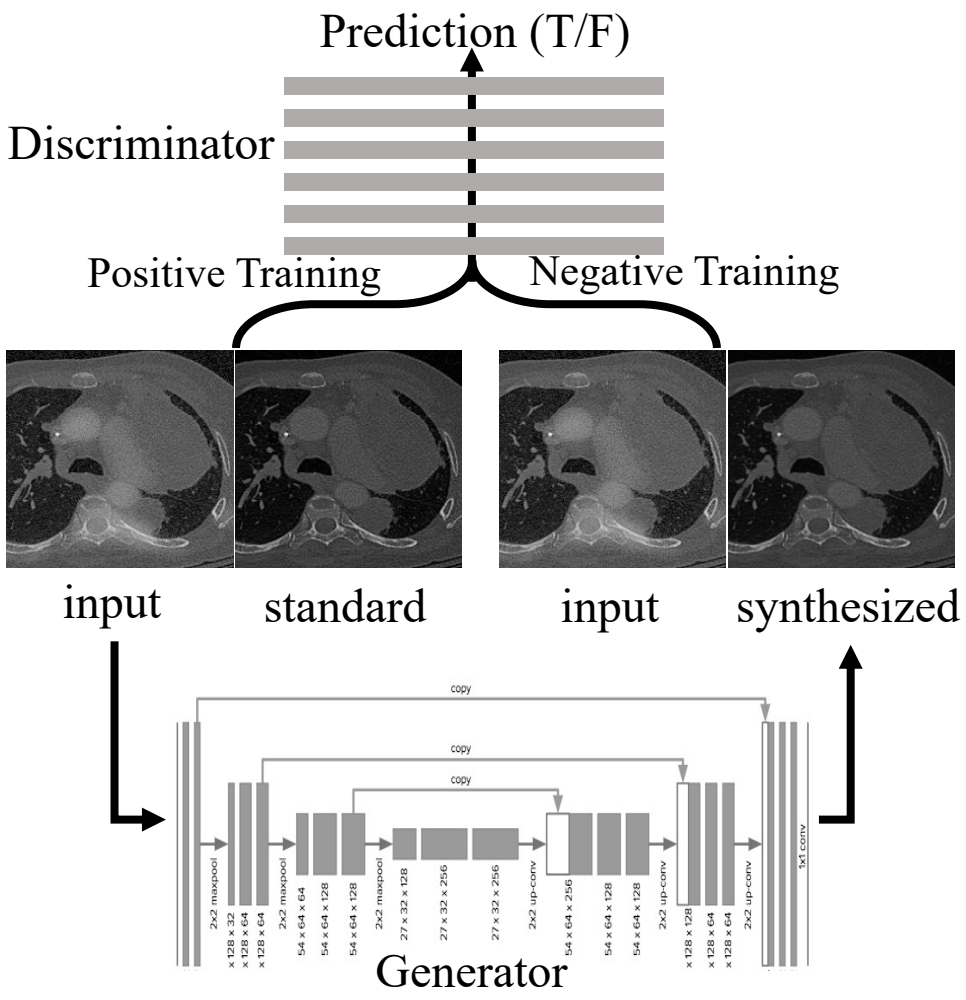
Zhu, Jun-Yan, et al. (2017). Unpaired image-to-image translation using cycle-consistent adversarial networks. *In IEEE International Conference on Computer Vision*

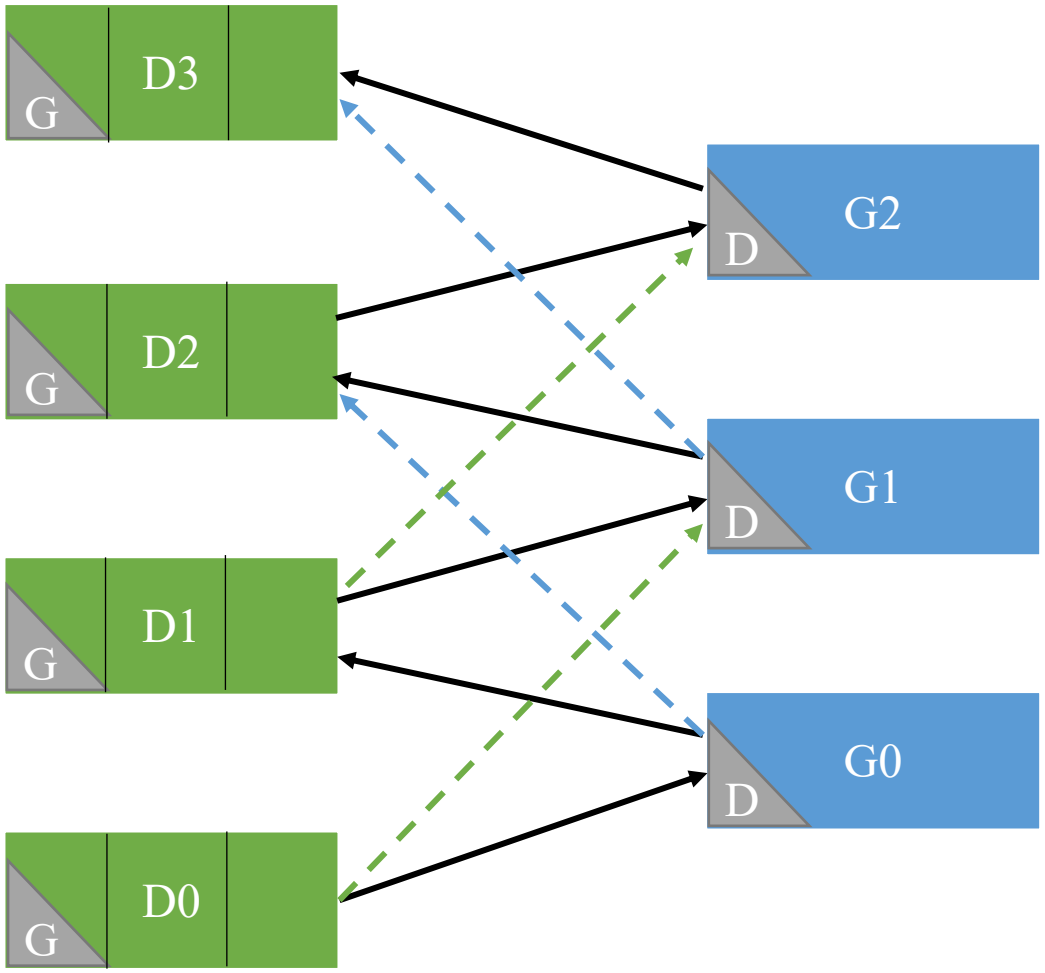
GAN Training Problem

- The balance between G and D must be carefully maintained for training to converge. Training problems in GAN:
  - **Mode Collapse**: G produces limited varieties of samples.
  - **Diminished gradient**: D gets too successful that the gradients vanish and the G learns nothing.
  - **Non-convergence**: the model parameters oscillate, destabilize and never converge.
  - **Overfitting**: cased by unbalance between G and D.
  - **Highly sensitive** to hyperparameters.
- The synthesized images may be lack of details.
- GAN treats every image equally, but in reality some CT images are more difficult to be standardized than the others.

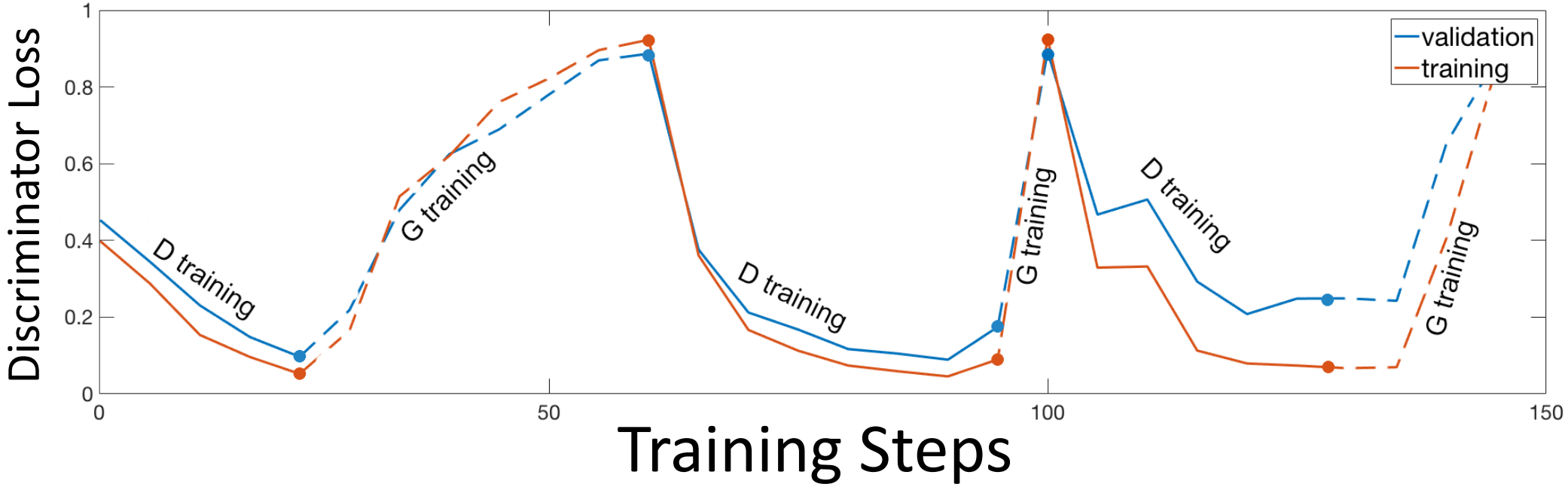
https://www.analyticsvidhya.com/blog/2017/06/introductory-generative-adversarial-networks-gans/

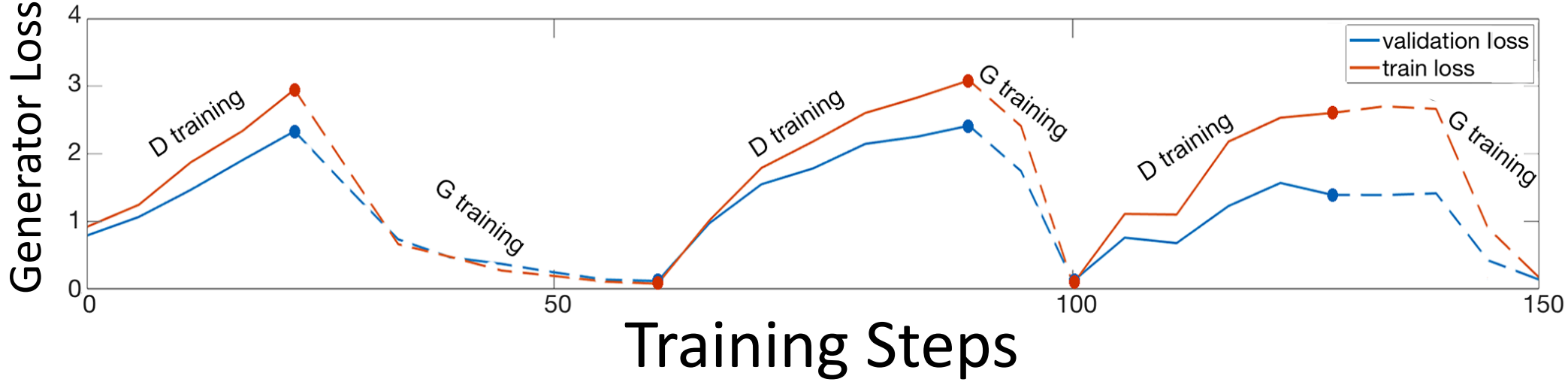
Architecture of STAN-CT





Liang, G., Fouladvand, S., Zhang, J., Brooks, M. A., Jacobs, N., & Chen, J. (2019). *GANai: Standardizing CT Images using Generative Adversarial Network with Alternative Improvement.* IEEE International Conference of Healthcare Informatics *2019*


Discriminator Loss
Training Steps
validation
training
D training
G training
D training
G training
D training
G training
0
0.2
0.4
0.6
0.8
1
0
50
100
150


Generator Loss
Training Steps
validation loss
train loss
D training
G training
D training
G training
D training
G training
0
1
2
3
4
0
50
100
150

Experimental Data

- Nine CT image datasets captured at UK hospital with a CT Somatom Force using different reconstruction kernels and slice thicknesses.
- In total 2,448 CT slices. Using data augmentation, we generated 14,958 paired image patches.
- Standard protocol: reconstruction kernel Bl64 and slice thickness 1mm.

Dataset	Kernel	Slice Thickness
1	Bl64	1 mm
2		1.5 mm
3		3 mm
4	Br40	0.5 mm
5		1 mm
6		1.5 mm
7		3 mm
8	Bl57	0.5 mm
9		1.5 mm

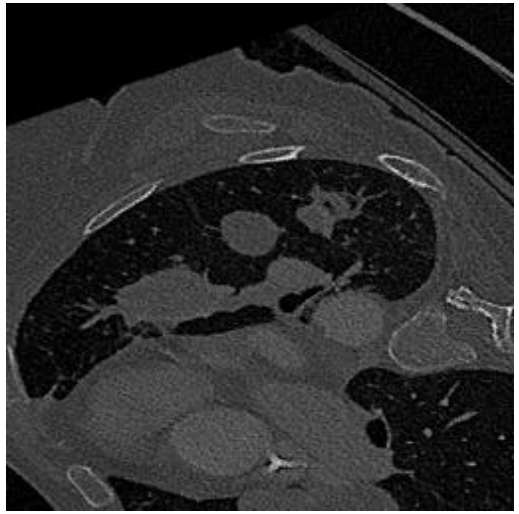
← Standard protocol

Absolute Error	Hist Matching	cGAN	STAN-CT
Contrast[1]	0.21 ±0.15	0.12 ±0.08	**0.09** ±0.06
Correlation[1]	0.18 ±0.13	0.18 ±0.12	**0.09** ±0.07
Dissimilarity[1]	0.15 ±0.11	0.09 ±0.06	**0.06** ±0.04
Energy[1]	0.47 ±0.28	0.19 ±0.14	**0.14** ±0.11
Entropy[1]	0.09 ±0.06	0.02 ±0.01	**0.01** ±0.01
Homogeneity[1]	0.28 ±0.16	0.10 ±0.06	**0.07** ±0.05
Kurtosis[2]	0.54 ±0.27	0.18 ±0.14	**0.15** ±0.11
Skewness[2]	0.51 ±0.27	0.16 ±0.12	**0.14** ±0.11

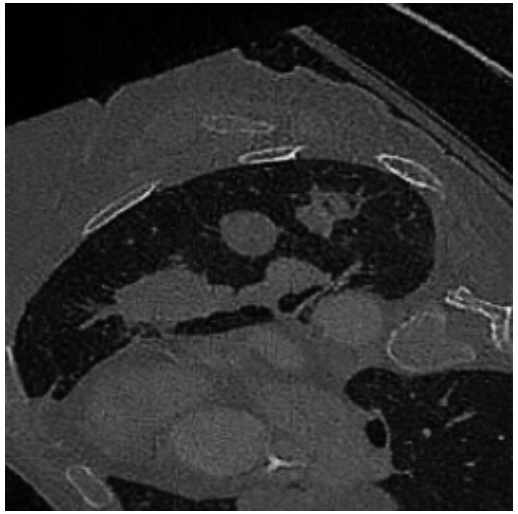
Averaged absolute errors (SD) of the texture features and the intensity histogram features computed using histogram matching, cGAN, and STAN-CT. STAN-CT has the smallest errors (two sample t-test p-value ≤ 0.01).

Bl57_0.5mm
To
Bl64_1mm

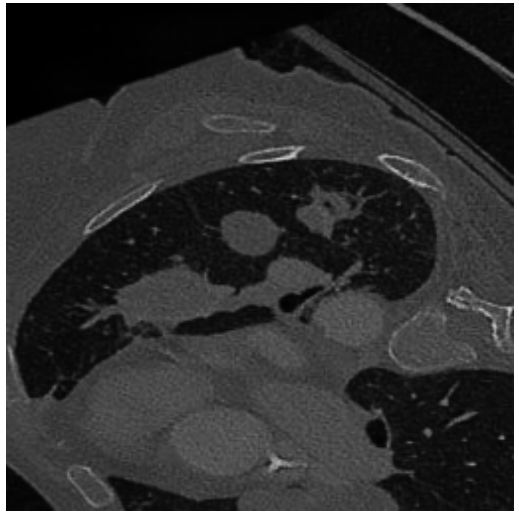
Source Image



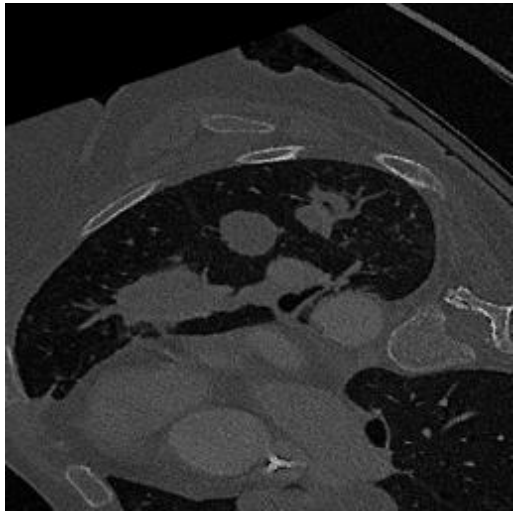
cGAN Output



STAN-CT Output

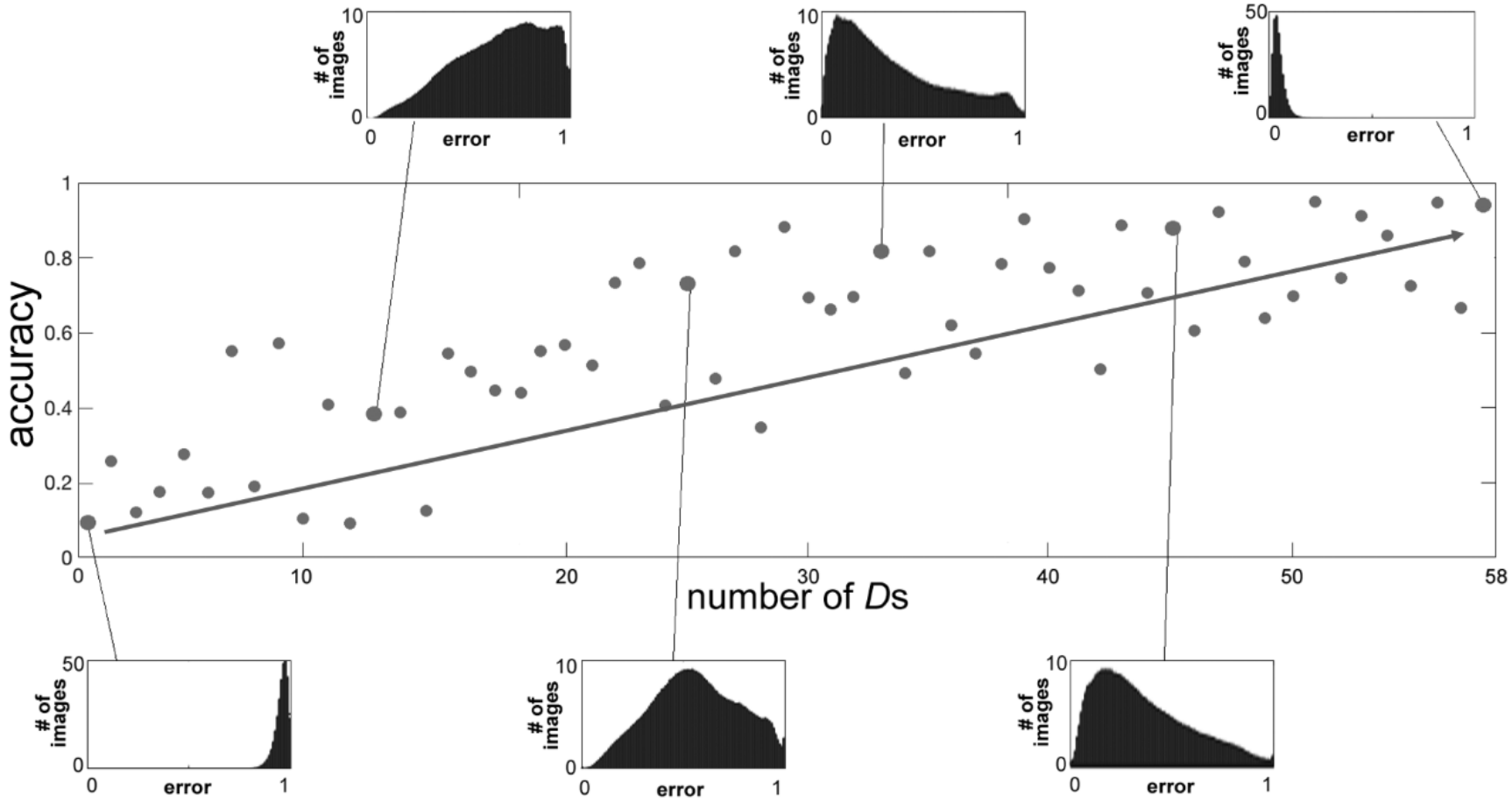


Target Image



GLCM-based Absolute Error		
	cGAN	STAN-CT
Contrast	0.06	0.04
Correlation	0.03	0.01
Dissimilarity	0.05	0.03
Energy	0.01	0.01
Entropy	0.07	0.03
Homogeneity	0.02	0.01

Performance of Discriminator on a Fixed Fake Image Set



Summary

- STAN-CT aims to standardize and normalize CT images to improve the quality control across different sites and enable the identification of advanced image traits to improve diagnosis and therapy response assessment.
- This study will facilitate quantitative cancer imaging and extraction of image features for better prognosis, where treatment is increasingly tailored based on critical radiomic image traits examined in large-scale and cross-site.
- The proposed imaging standardization tools will be shared with the cancer research community to promote multi-center clinical trials of lung cancer diagnosis and treatment.