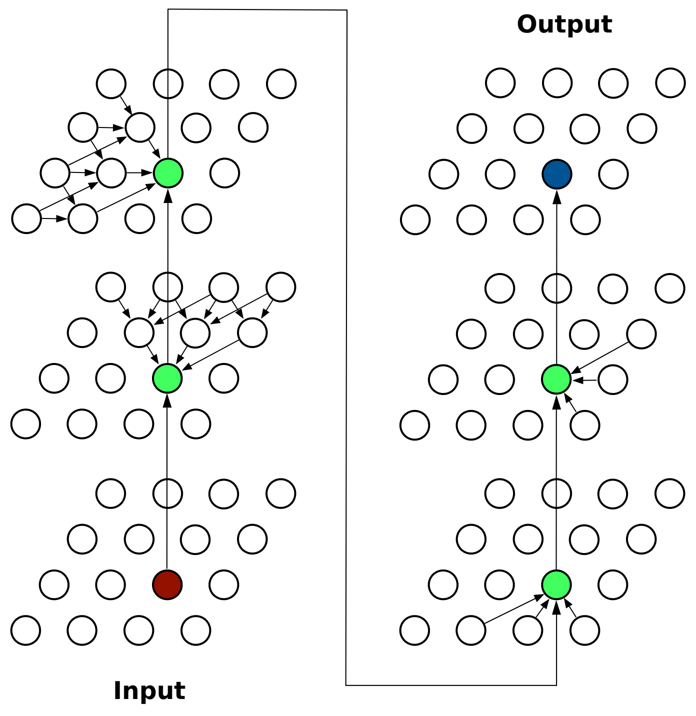

Spatial Dependency Networks

Neural Layers for Improved Generative Image Modeling

Đorđe Miladinović, Aleksandar Stanić, Stefan Bauer, Jürgen Schmidhuber & Joachim M. Buhmann

GitHub @djordjemila

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ETH Zürich

USI/SUPSI IDSIA Istituto Dalle Molle di studi sull'intelligenza artificiale

USI Università della Svizzera italiana

Max Planck Institute for Intelligent Systems

ICLR 2021

Motivation: Image Generation

(Miladinović et al. 2021)

Motivation: Image Generation

realistic image synthesis **[this work]**

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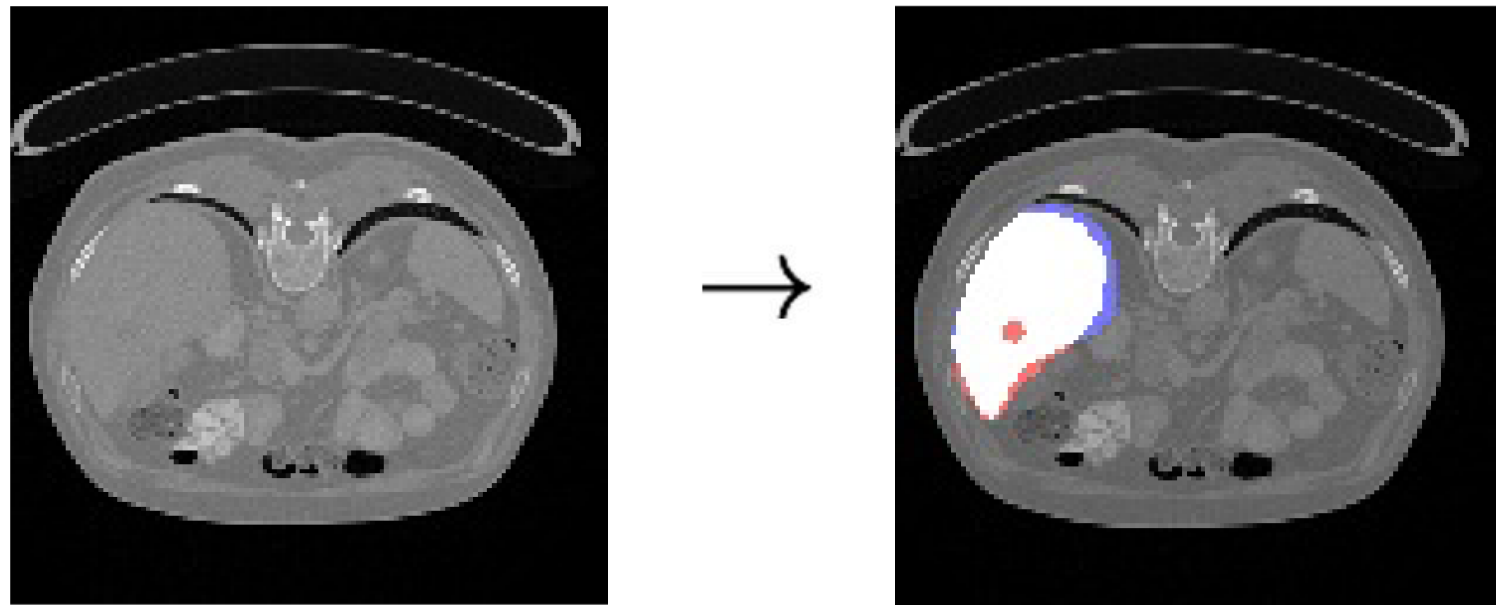

segmentation [Carvalho et al. 2021] **[follow-up]**

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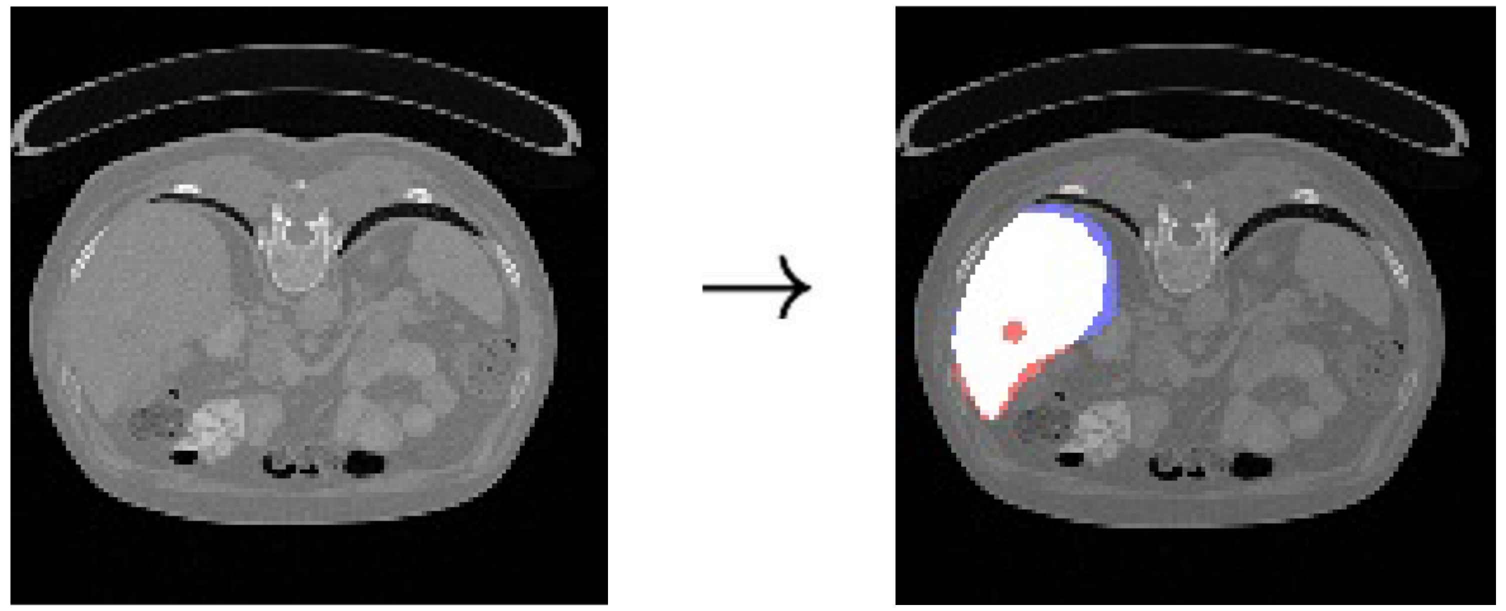

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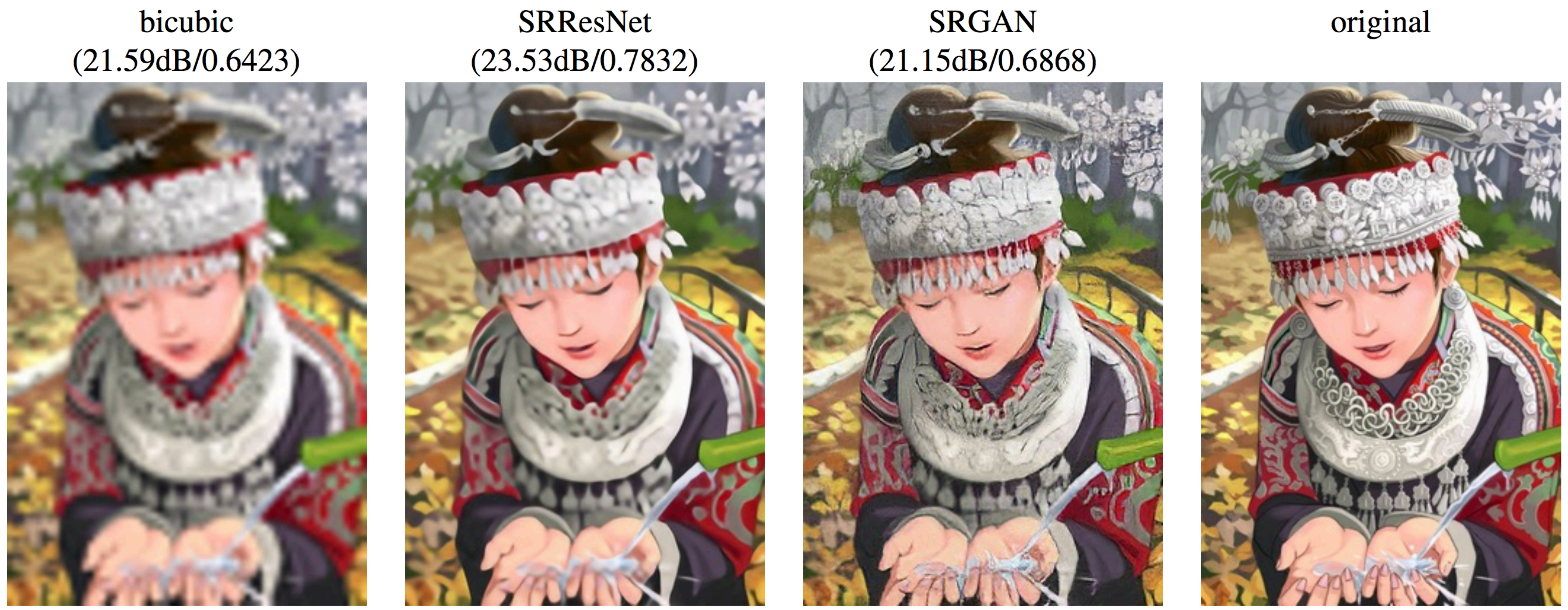

super-resolution [Ledig et al. 2017]

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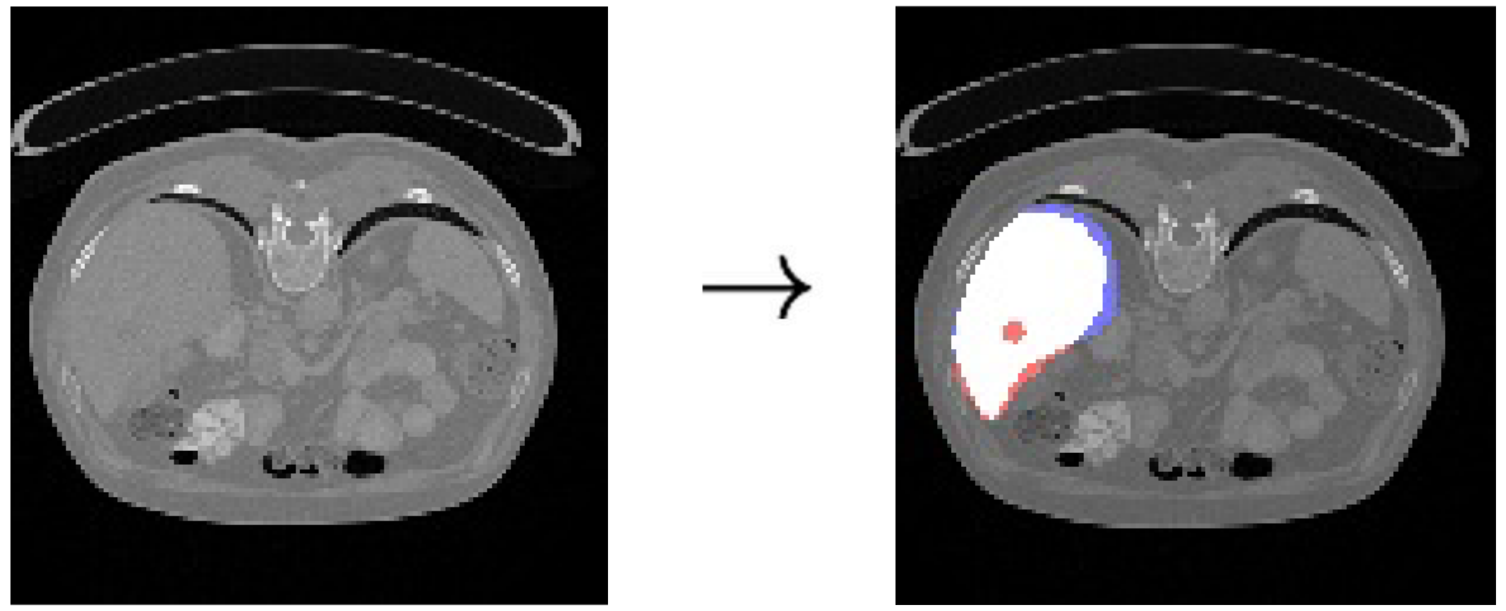

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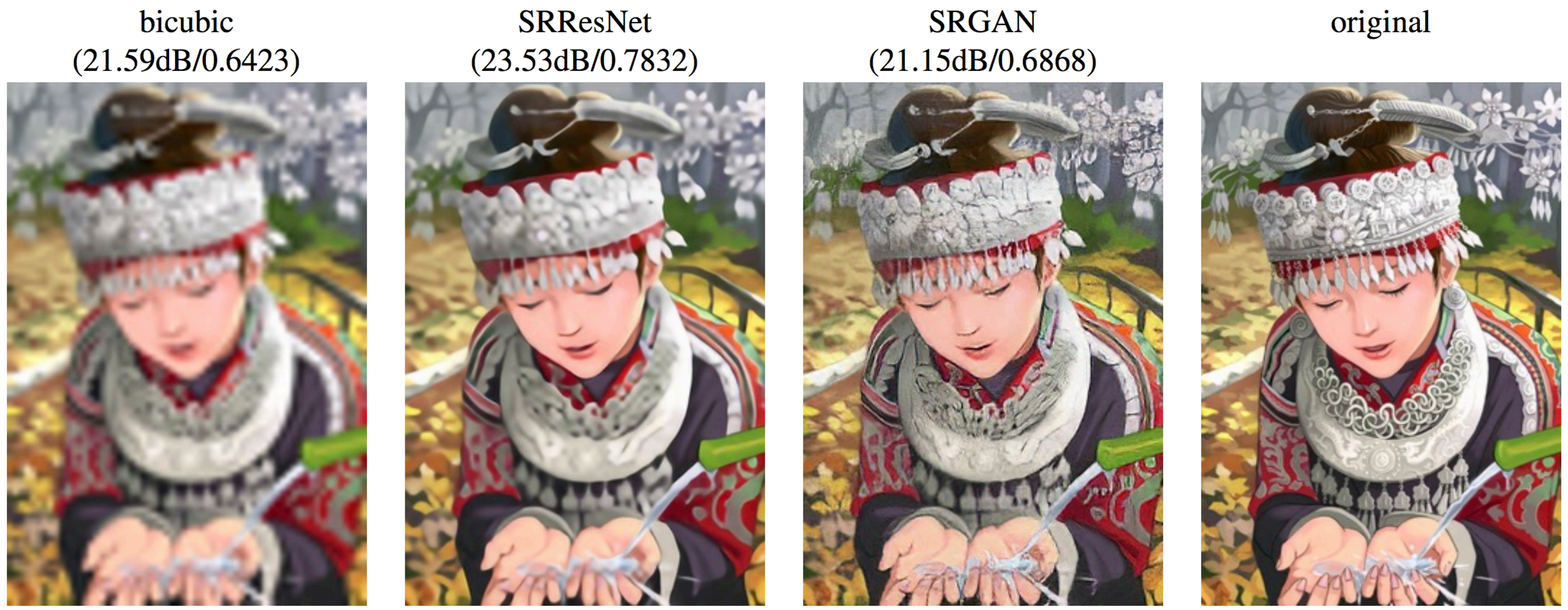


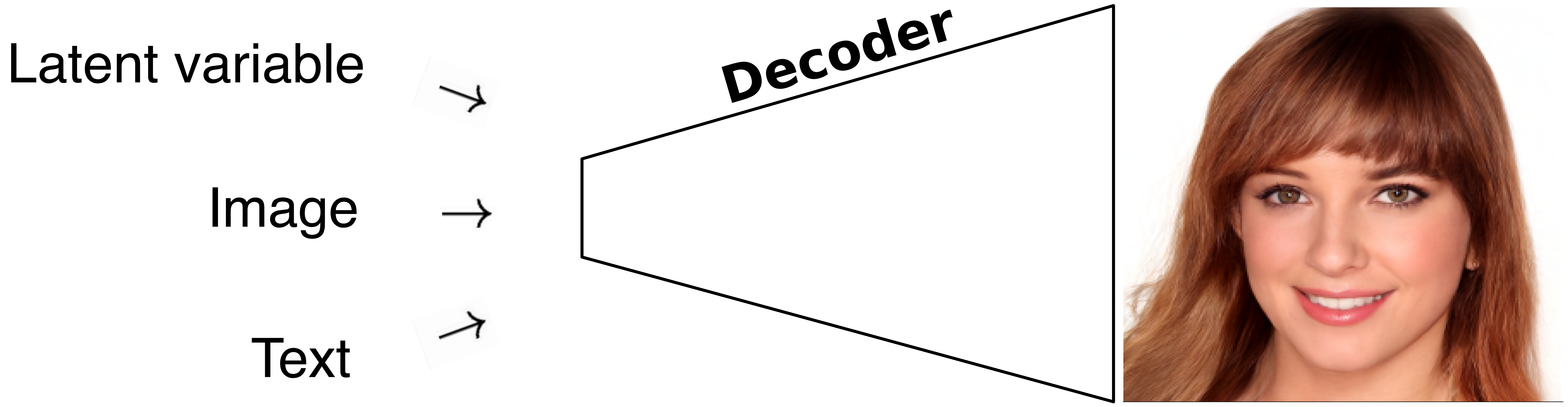
super-resolution [Ledig et al. 2017]

image-to-image translation

[Zhu et al. 2017]

(Miladinović et al. 2021)

Image Generation requires an Image Decoder/Generator



(Miladinović et al. 2021)

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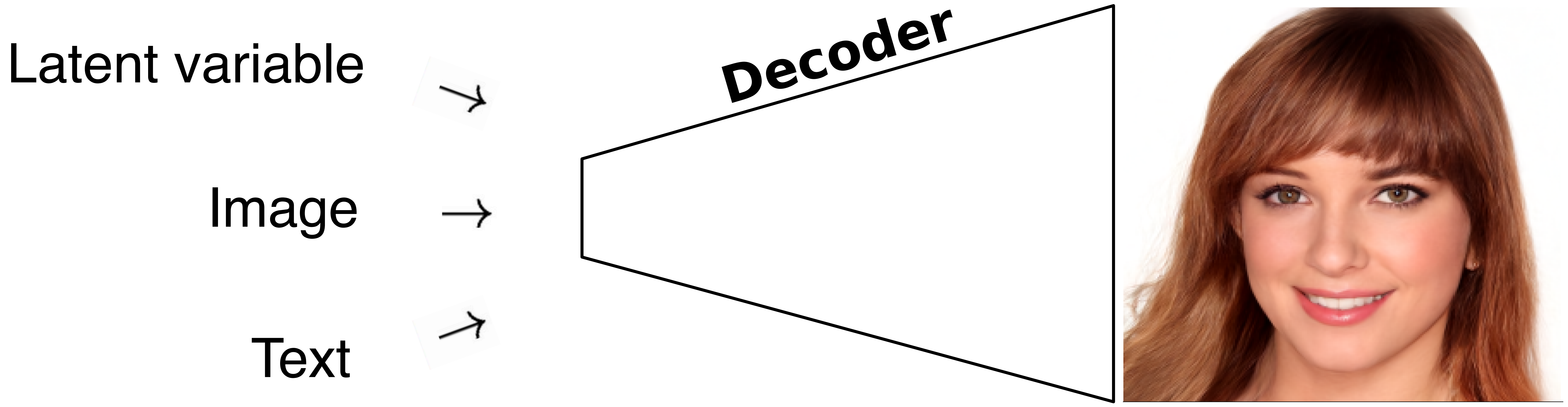

Focus of this paper: **Variational Autoencoders** [Kingma et al. 2013].

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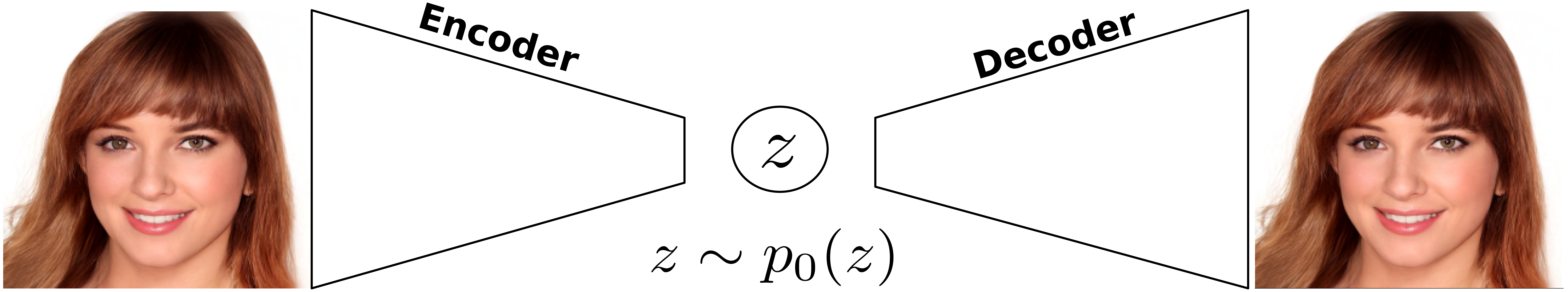

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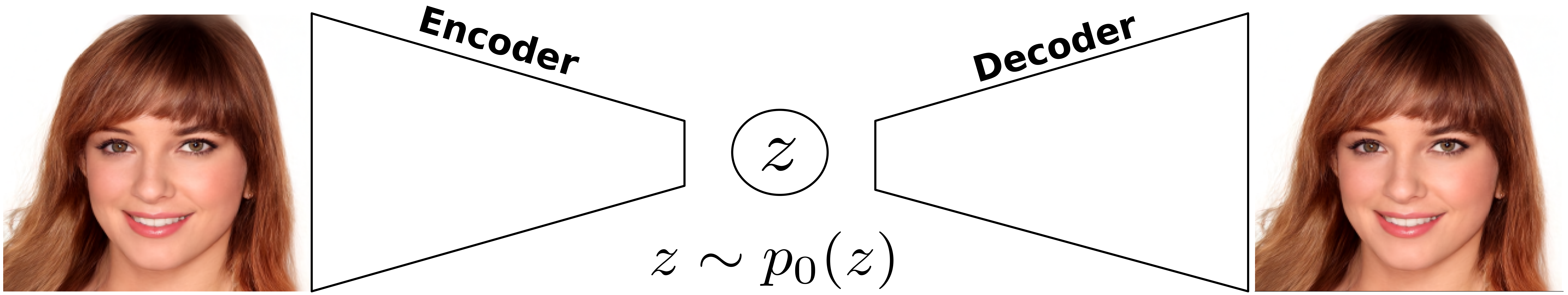

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Our hypothesis:

- Convolutional network (CNN) — good in extracting patterns from images — encoding.
- **Spatial dependency network (SDN)** — better in synthesizing images — decoding.

(Miladinović et al. 2021)

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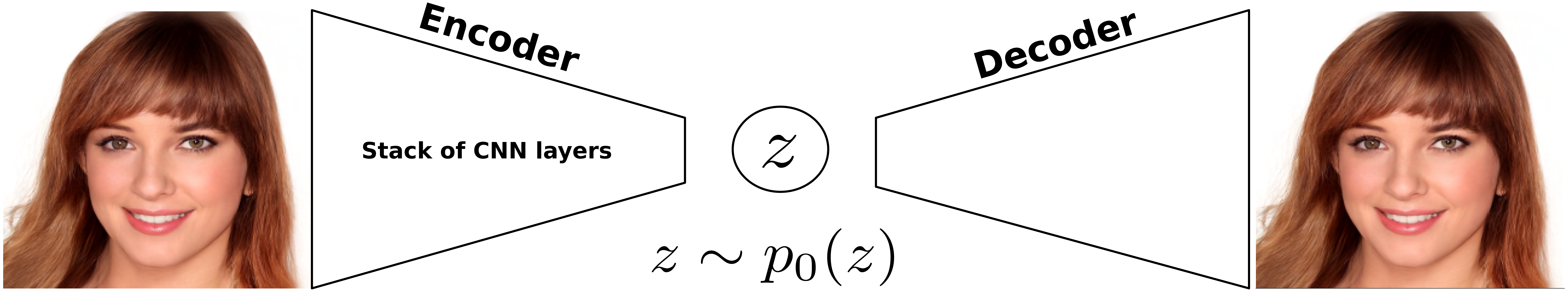

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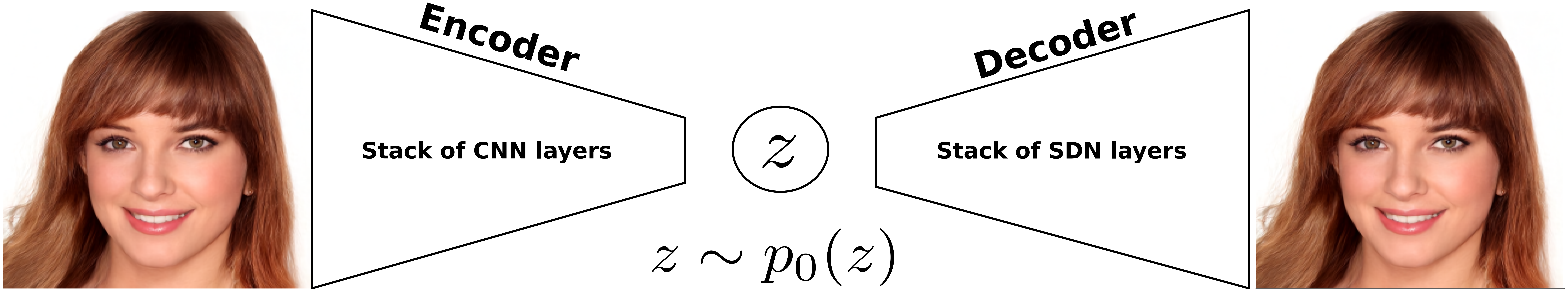

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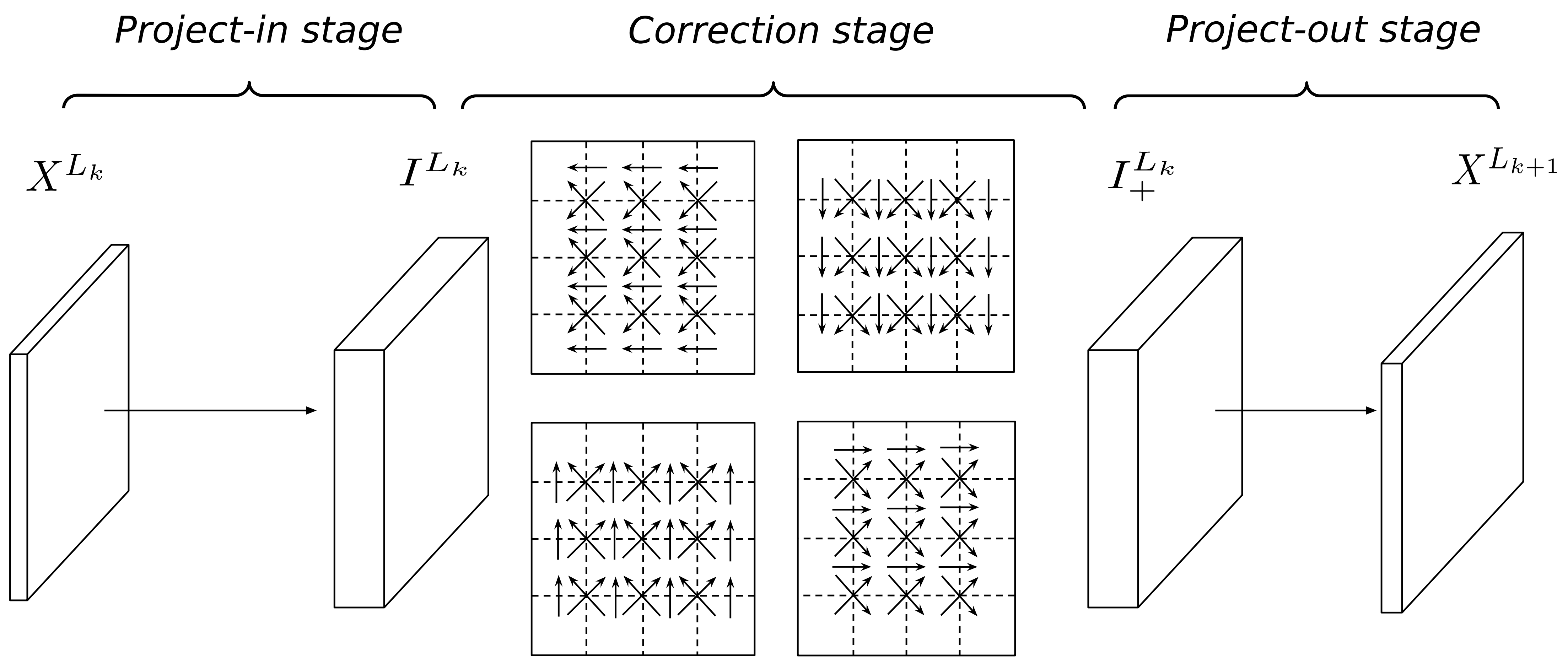
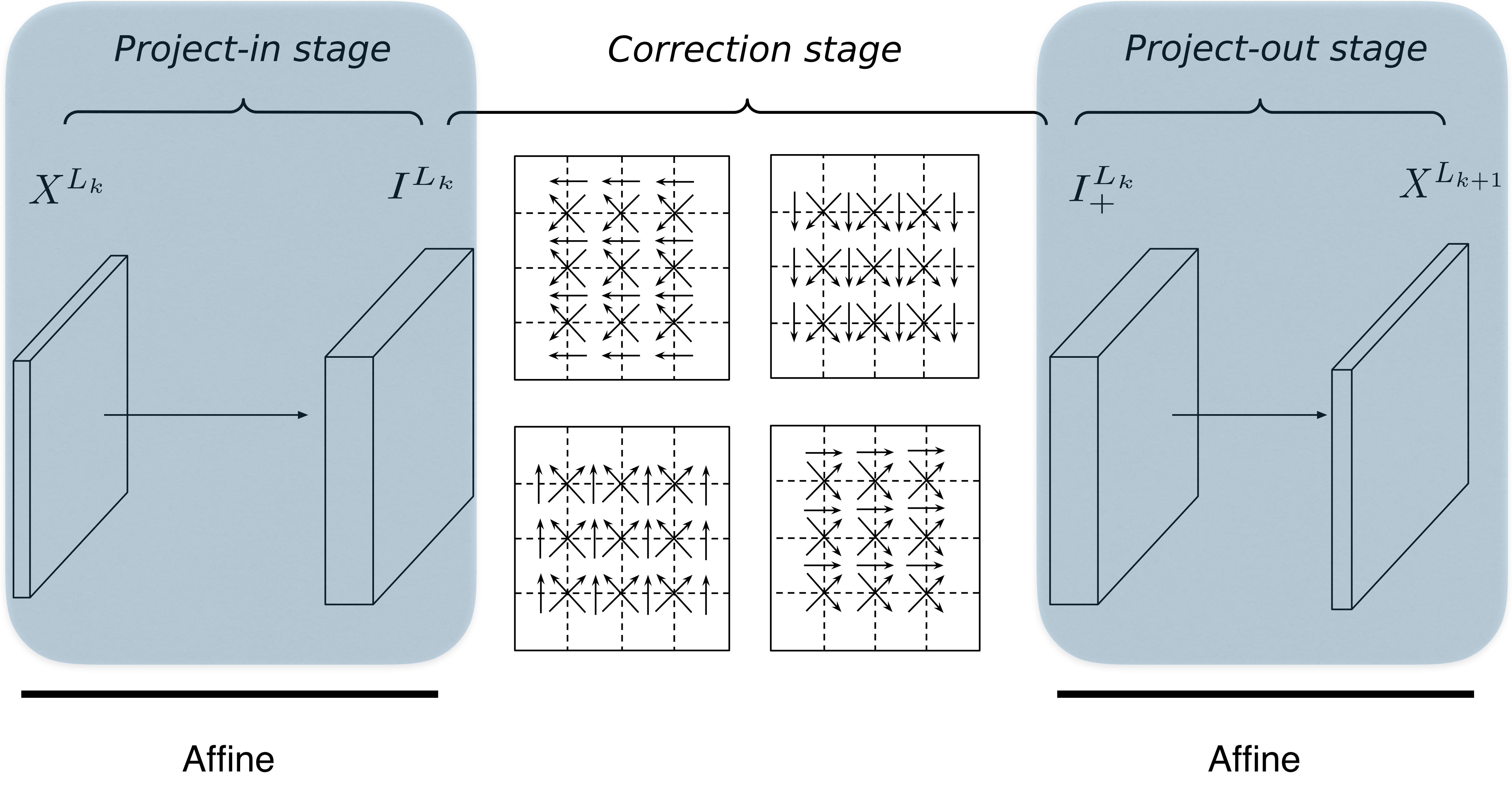
Spatial Dependency Network (SDN)



Computational flow of an SDN layer.

(Miladinović et al. 2021)

Spatial Dependency Network (SDN)



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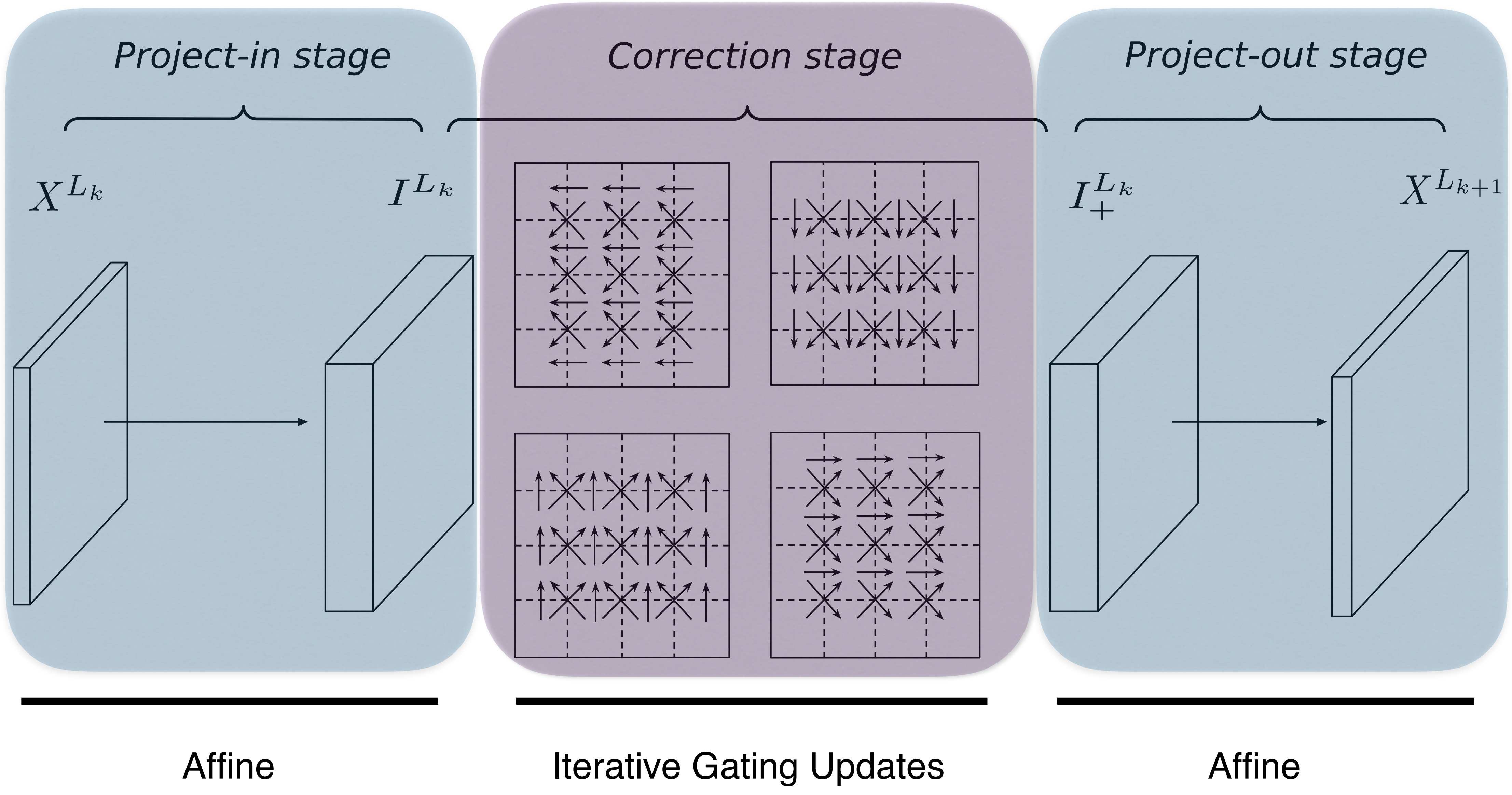

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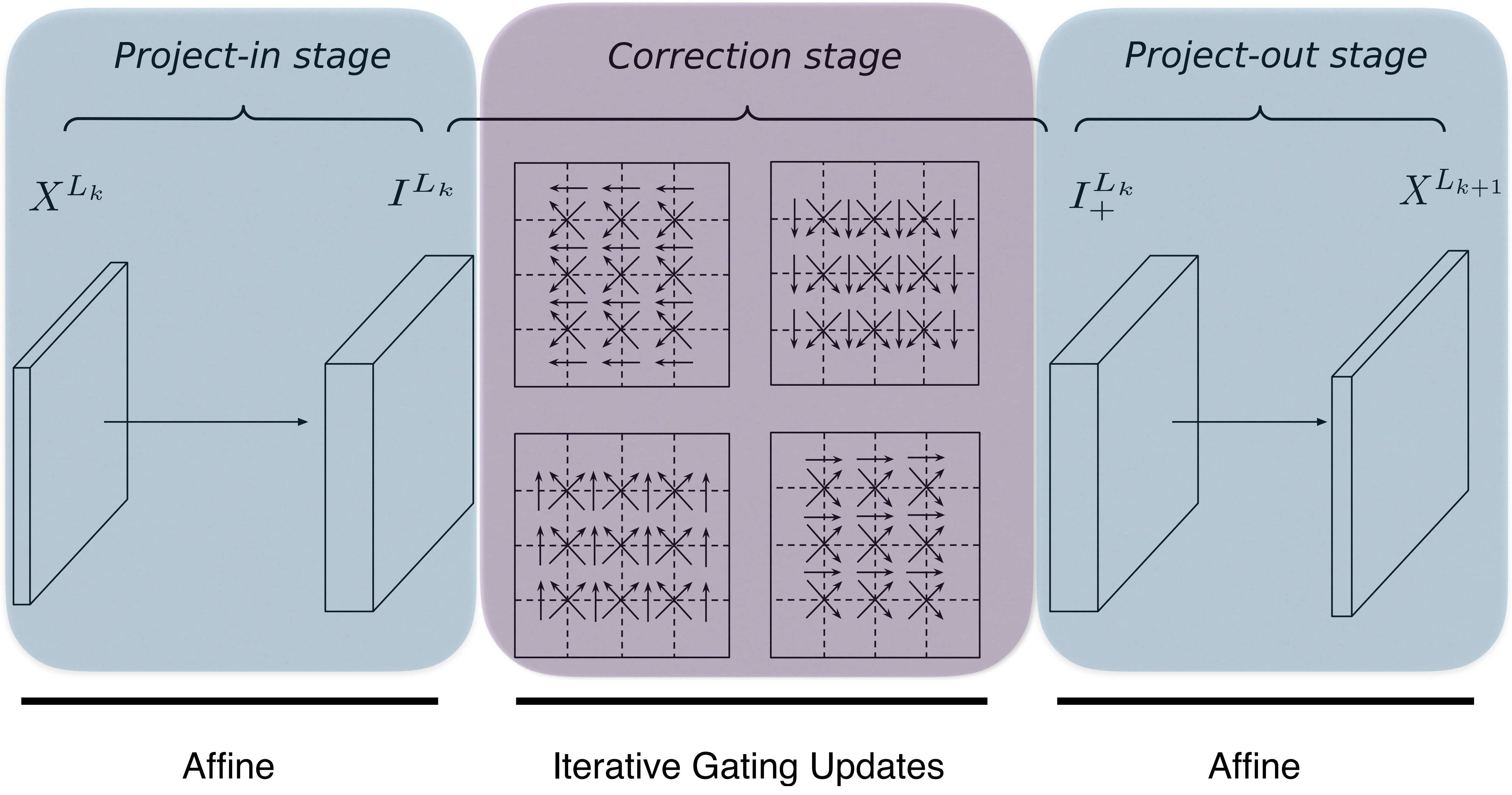

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SDN layers:

(Miladinović et al. 2021)

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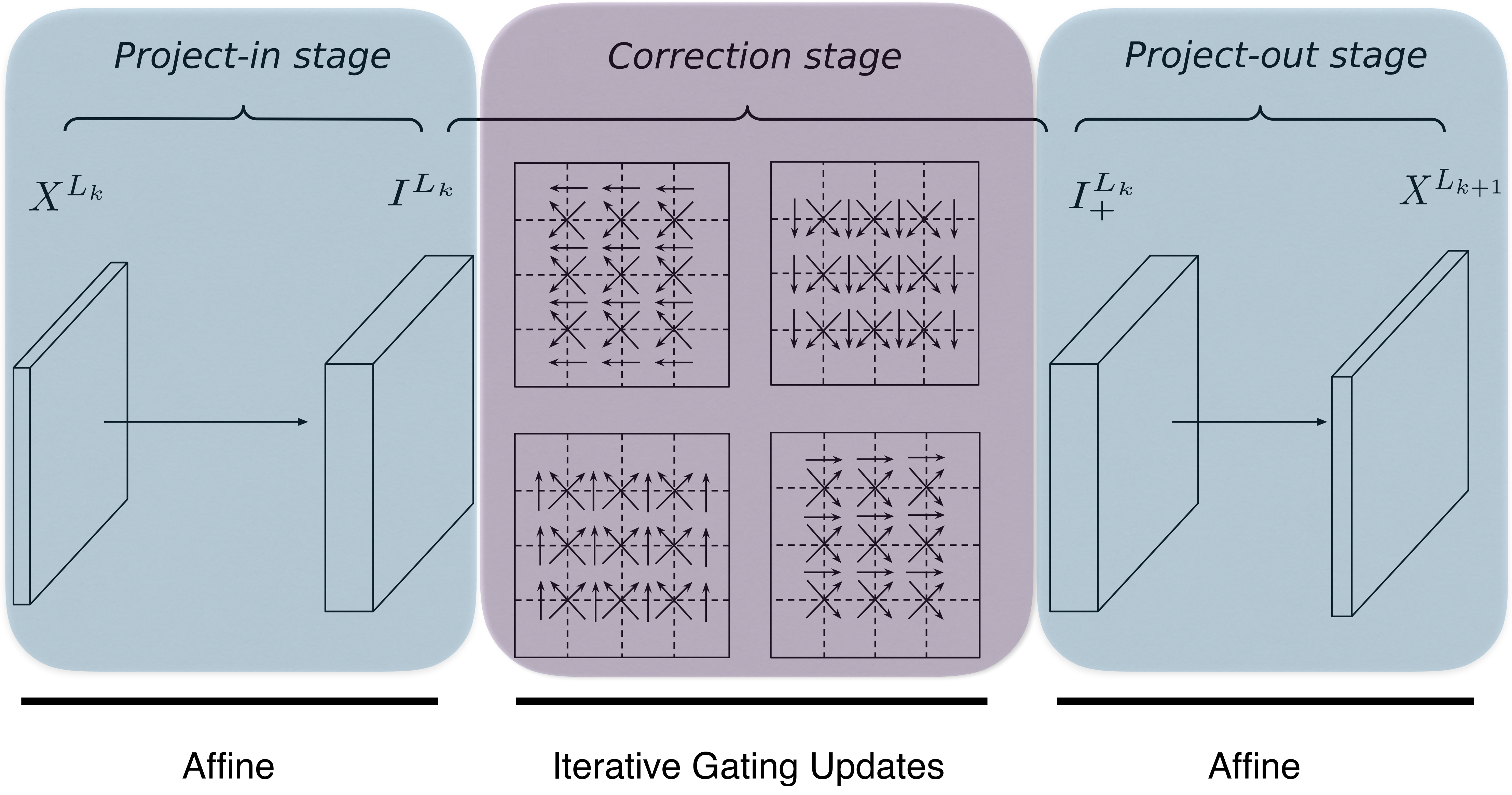

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SDN layers:

1. **enforce spatial coherence** — the similarity of neighboring feature vectors.

(Miladinović et al. 2021)

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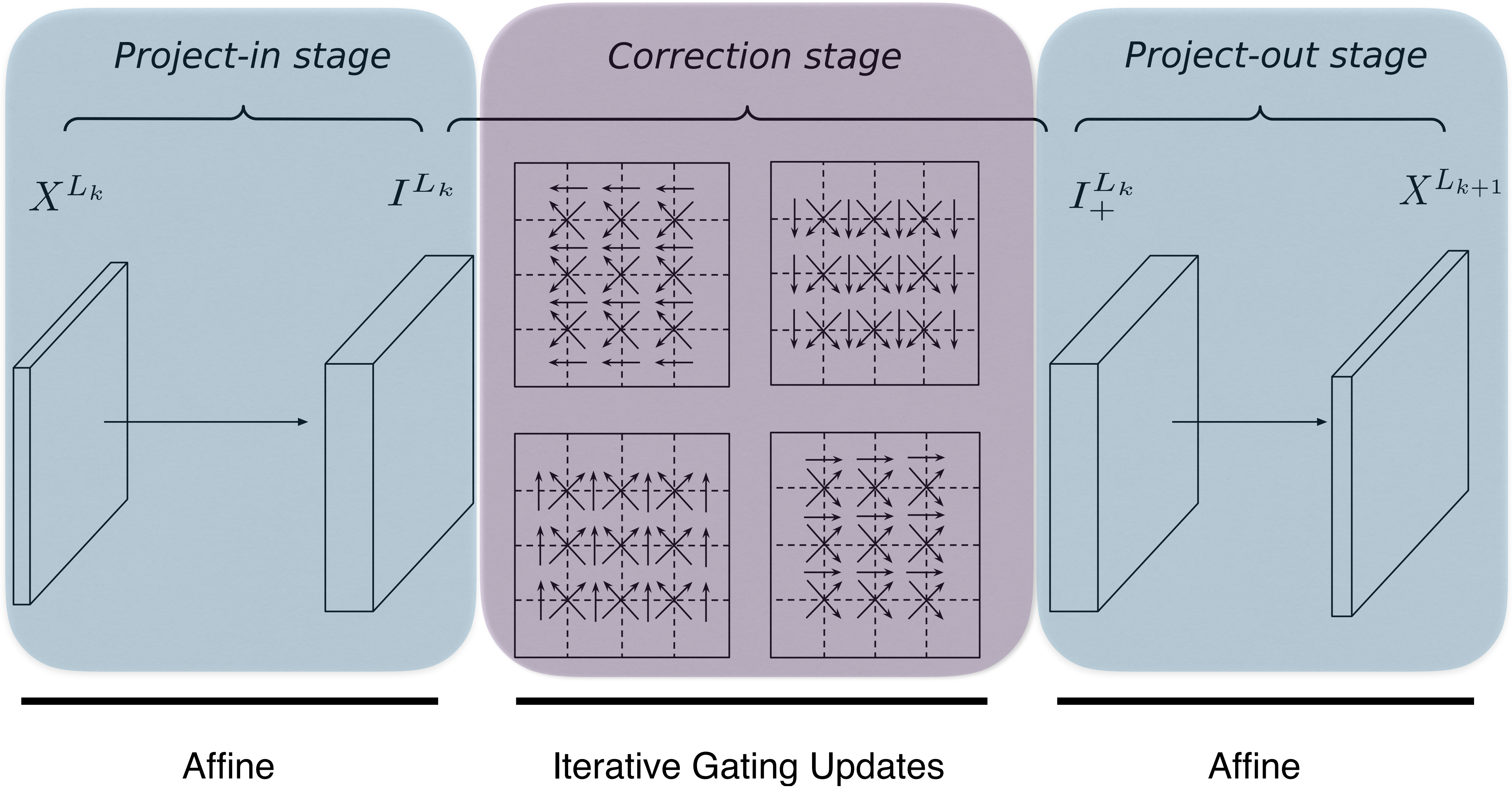

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SDN layers:

1. **enforce spatial coherence** — the similarity of neighboring feature vectors.
2. **model long-range spatial dependencies** at each level of a NN.

(Miladinović et al. 2021)

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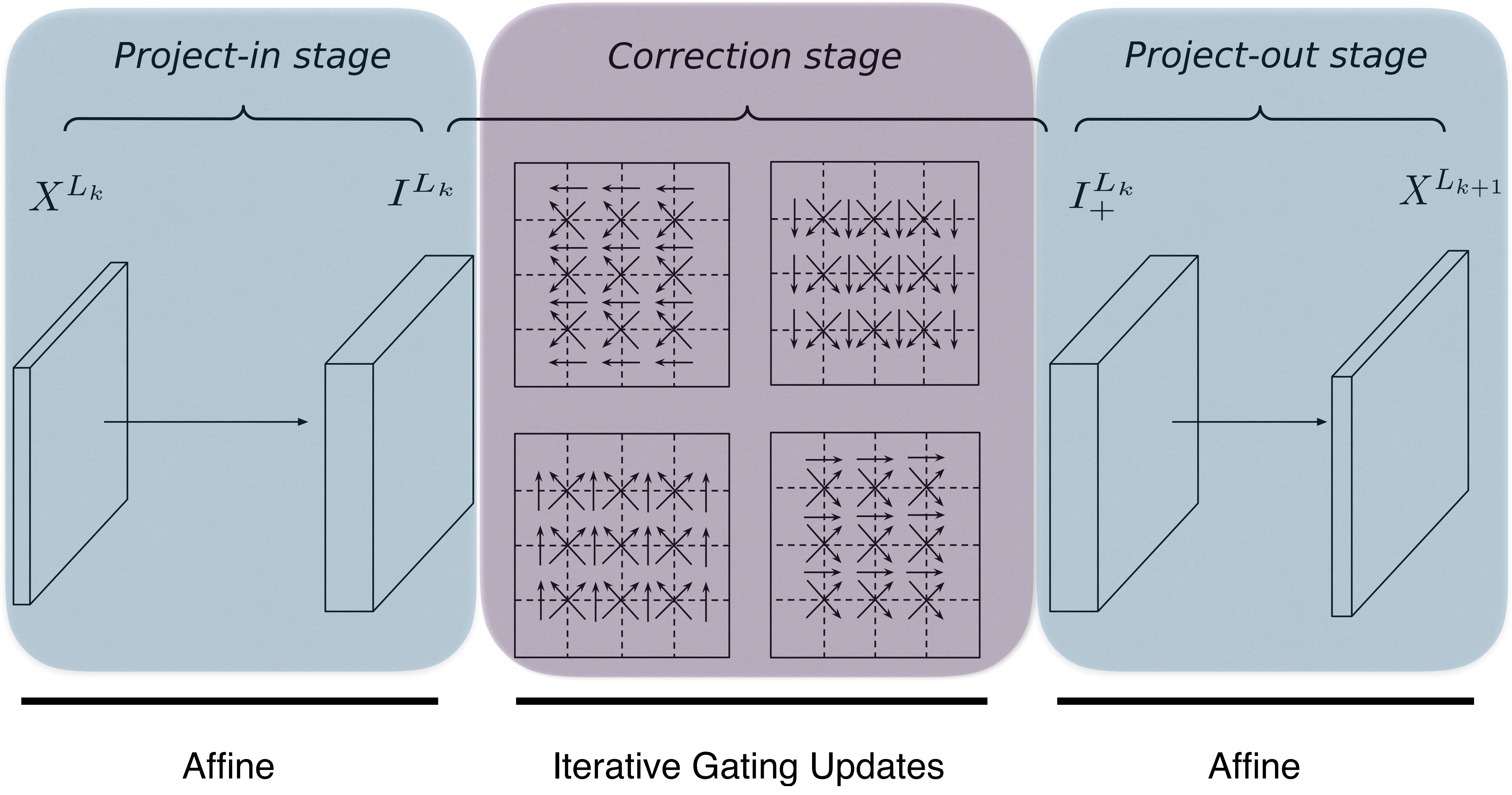

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1. **enforce spatial coherence** — the similarity of neighboring feature vectors.
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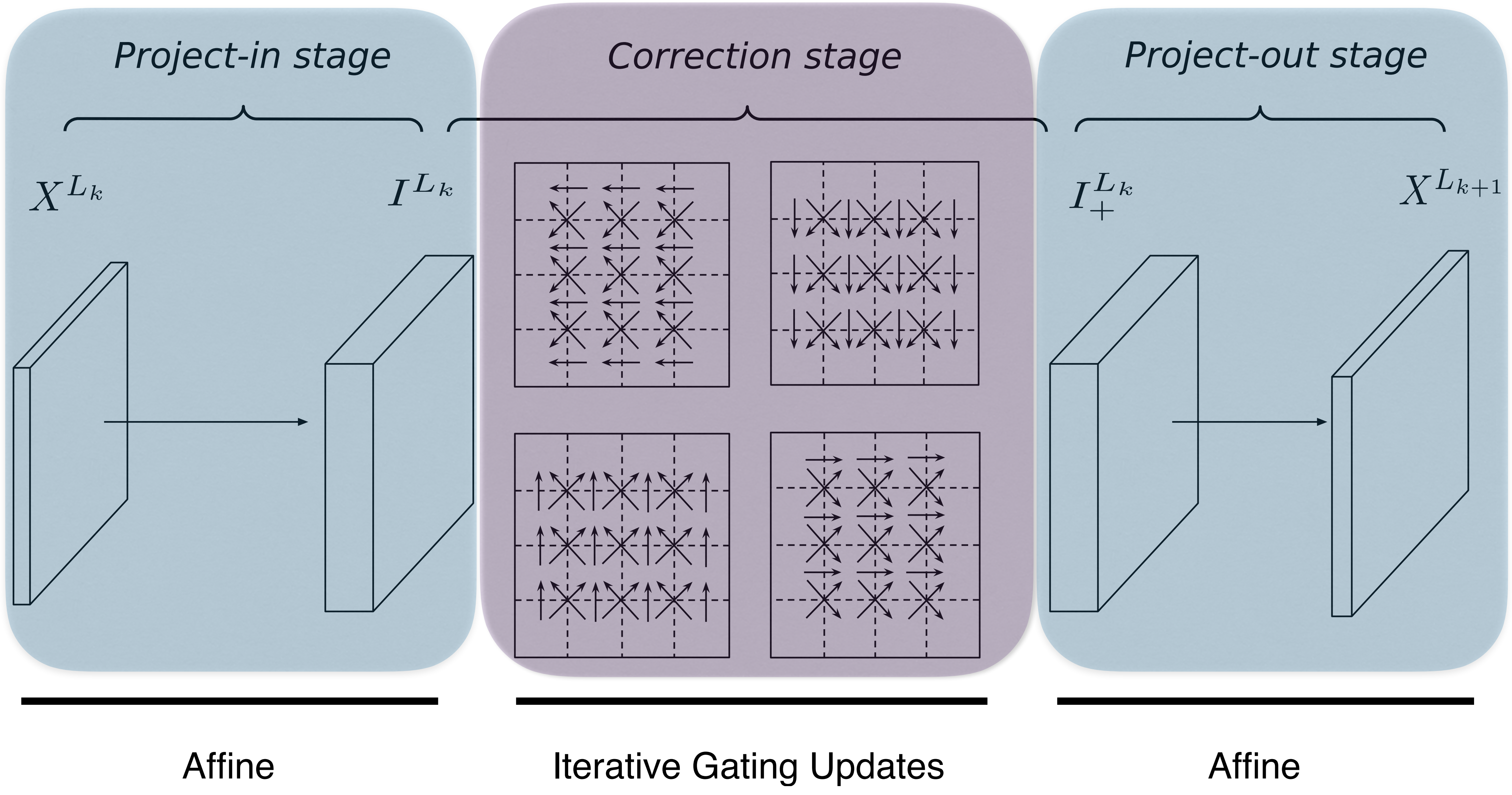
(Miladinović et al. 2021)

Spatial Dependency Network (SDN)



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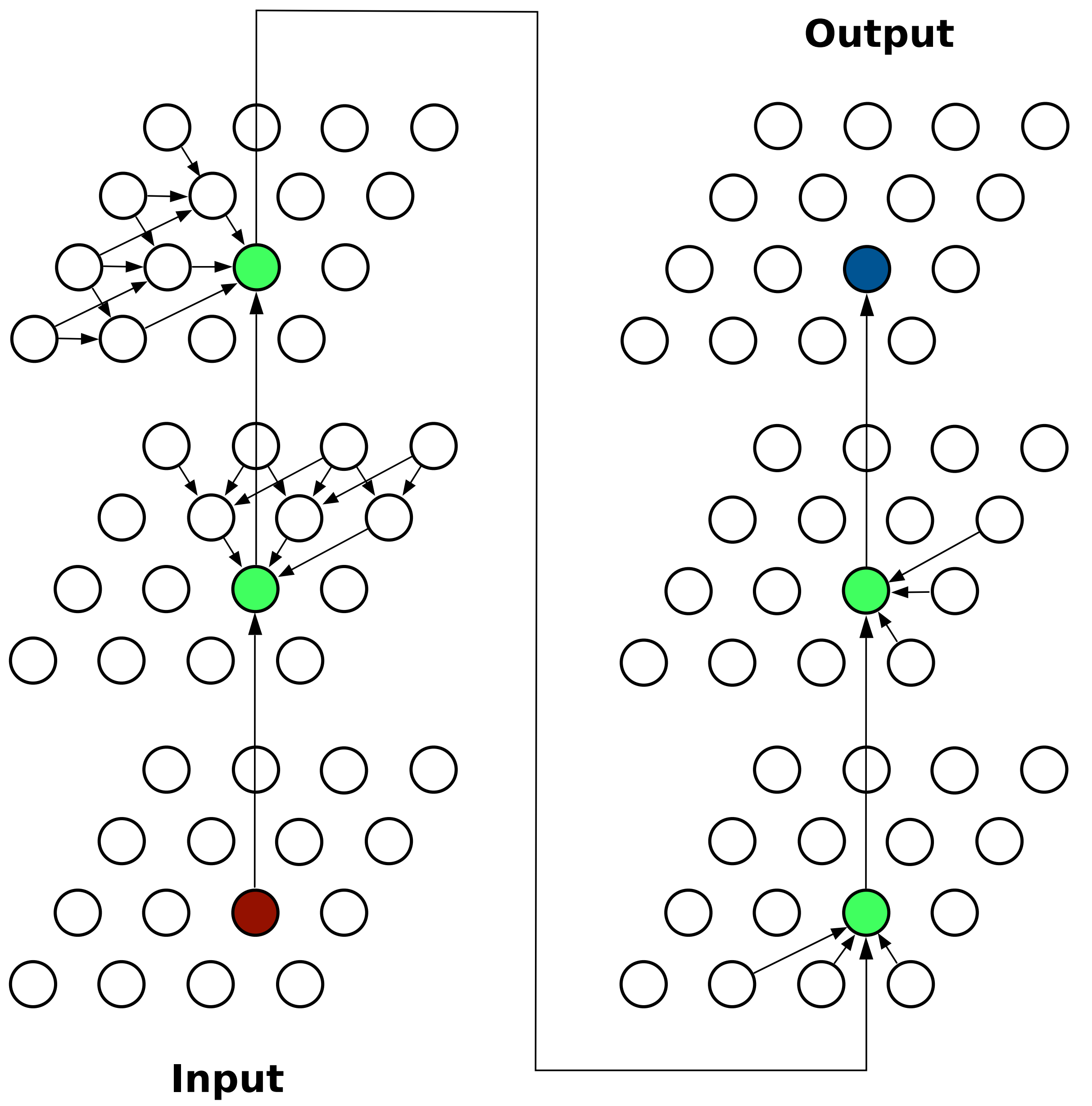

Graphical model of an SDN layer.

SDN layers:

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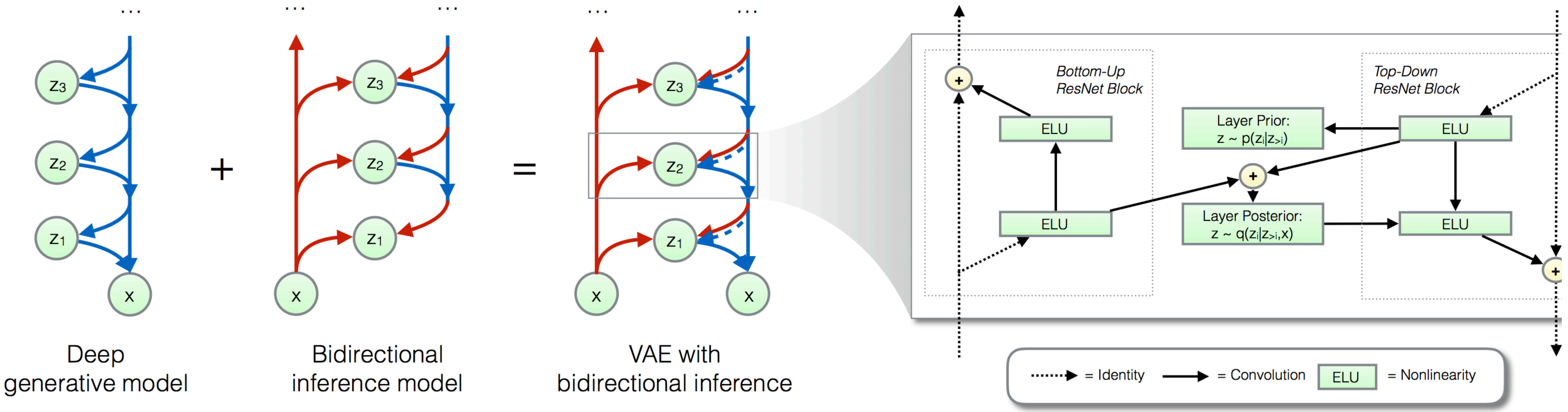
SDN-VAE: IAF-VAE enhanced with SDN layers



IAF-VAE: Hierarchical (Ladder) VAE [Sønderby et al. 2016] with ResNet blocks [Kingma et al. 2017]

(Miladinović et al. 2021)

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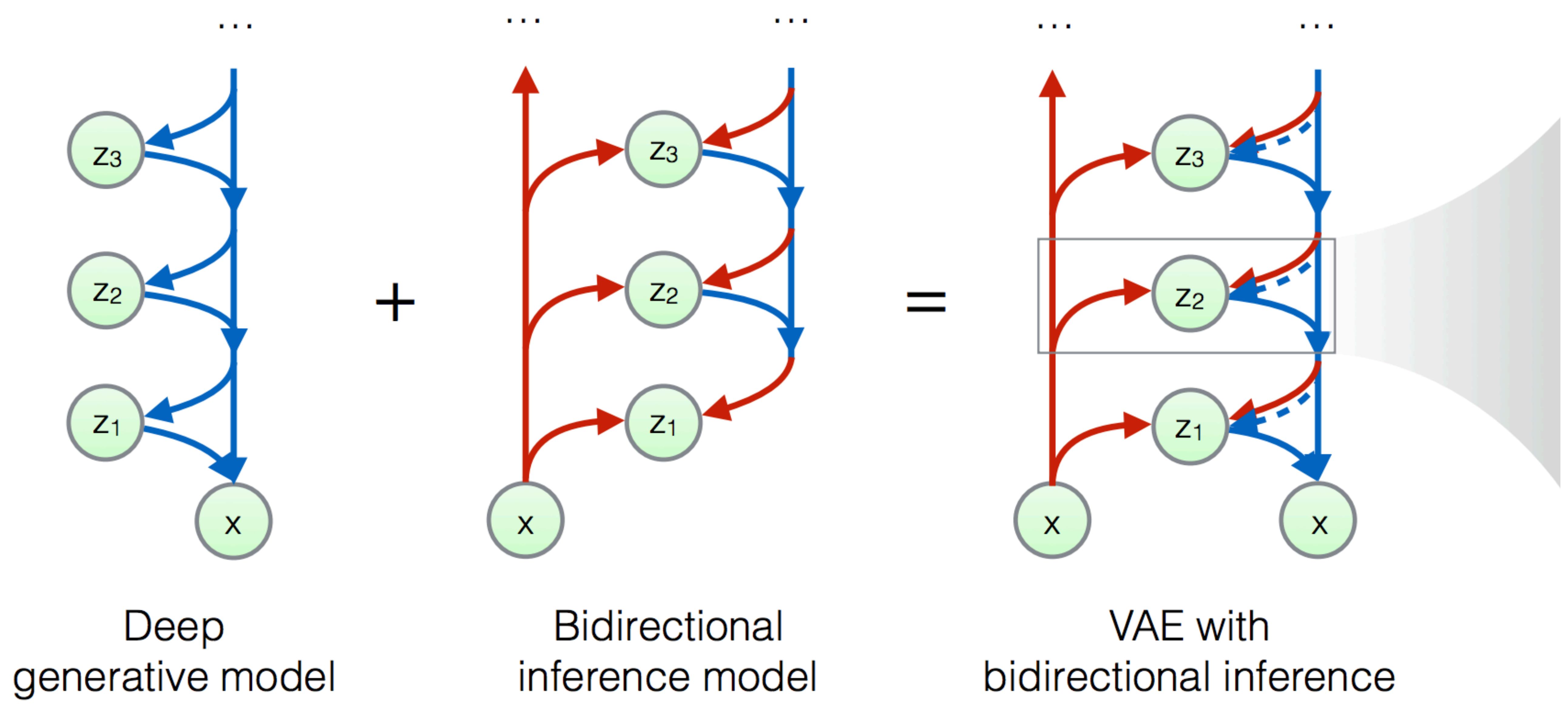

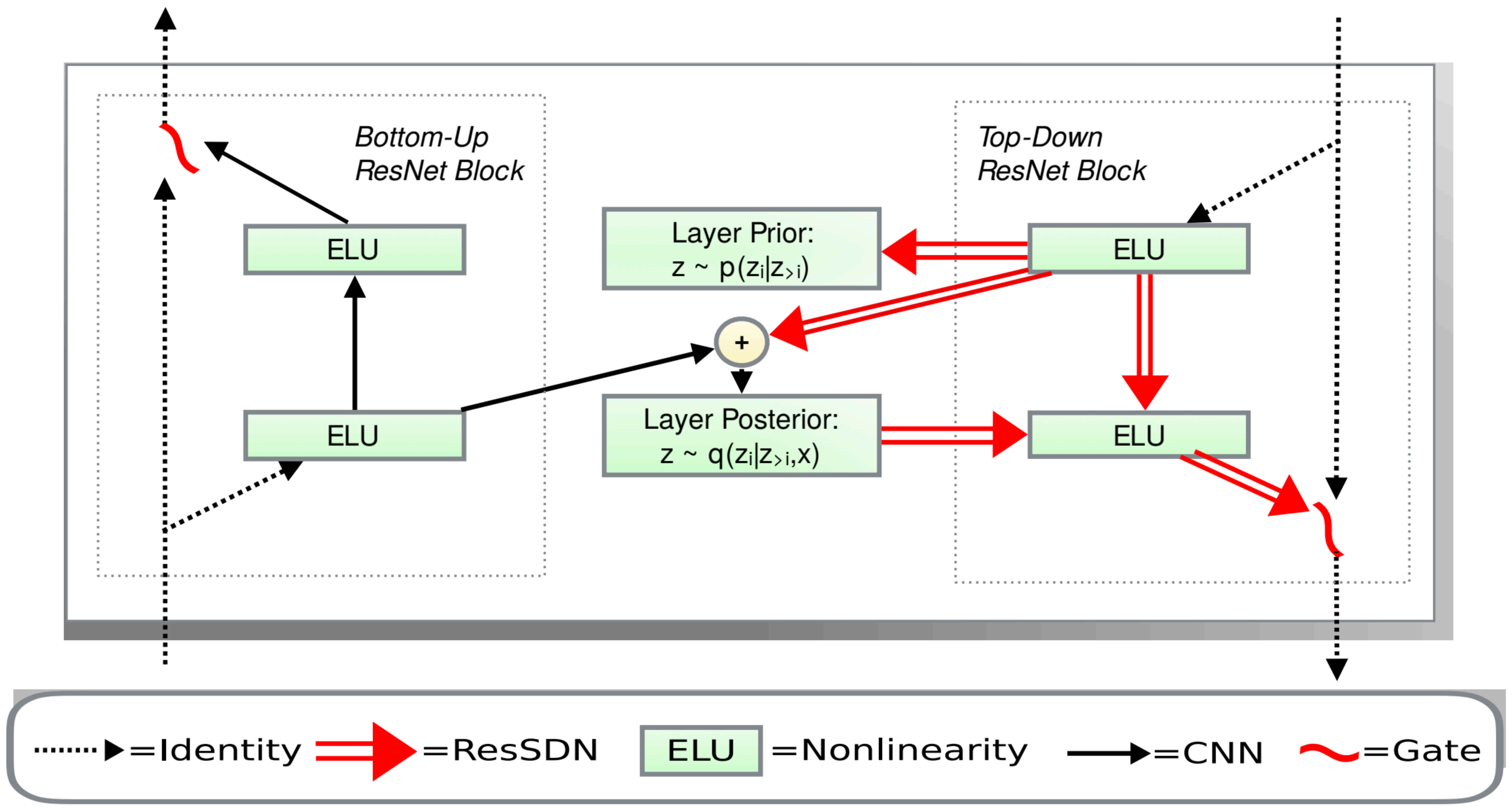

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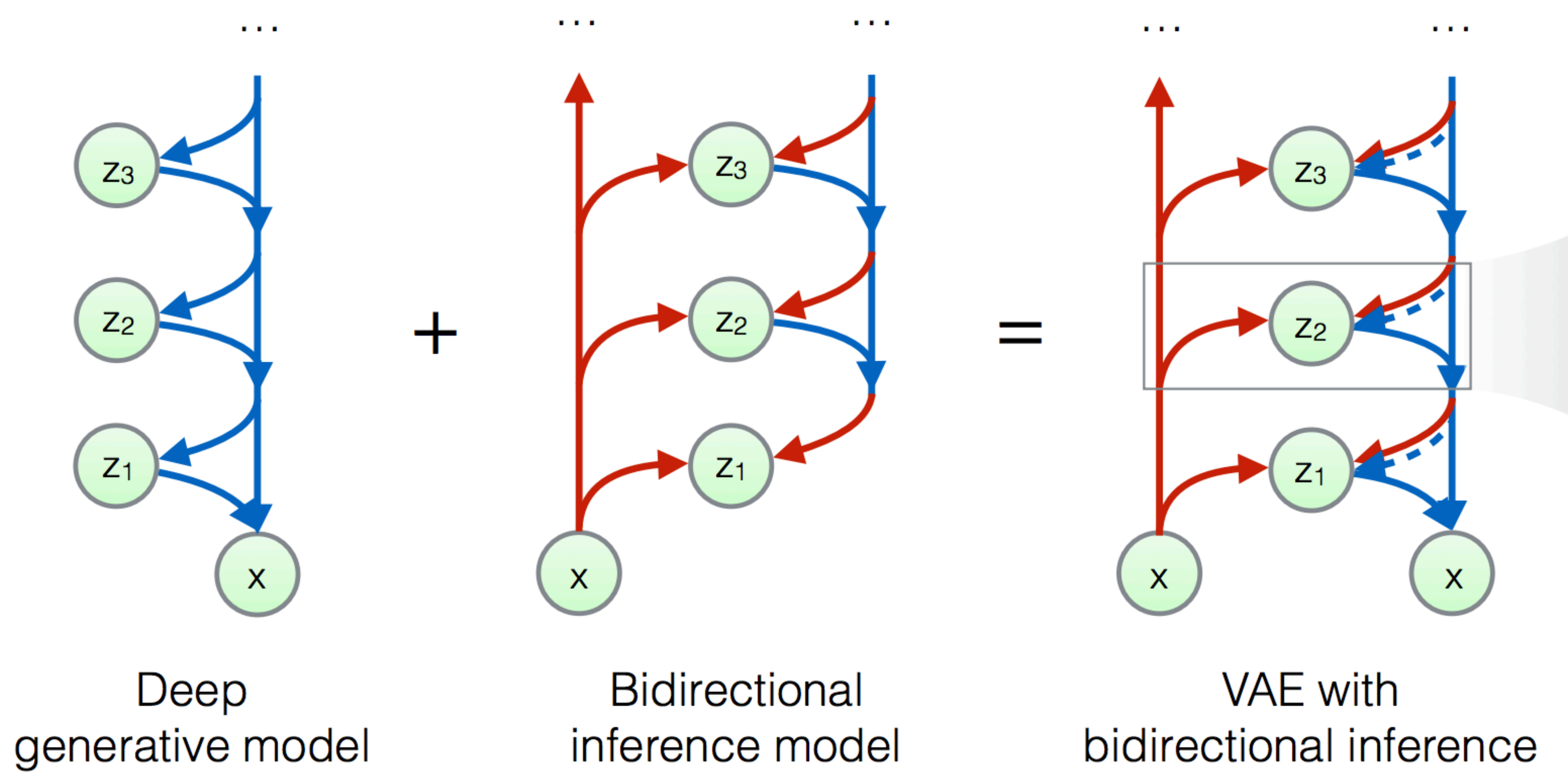

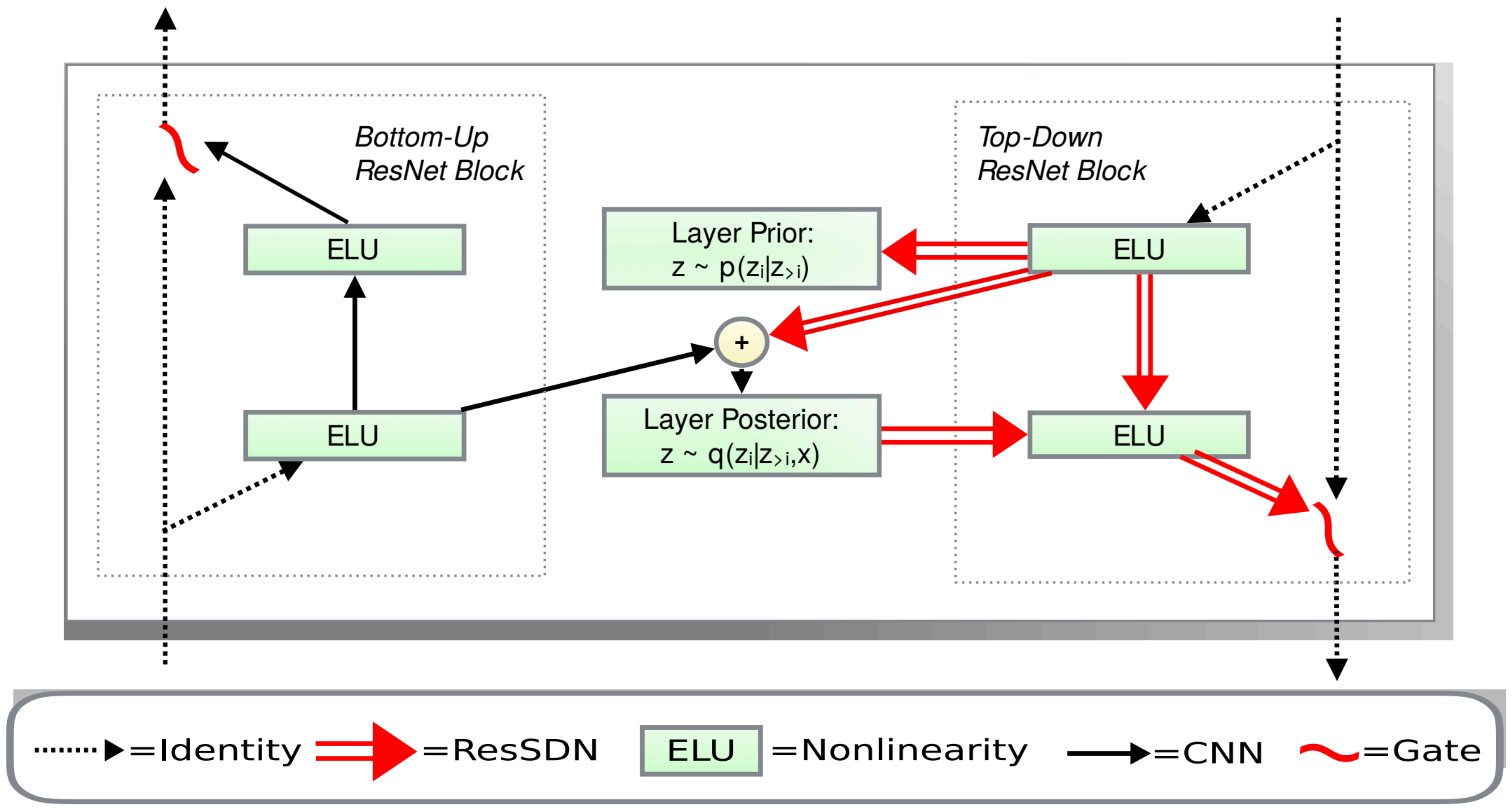

IAF-VAE: Hierarchical (Ladder) VAE [Sønderby et al. 2016] with ResNet blocks [Kingma et al. 2017]

with additional modifications:

- Mixed-precision [Micikevicius et al. 2017]
- Gated "highway" residual [Srivastava et al. 2015]
- Discretized Mixture of Logistics [Salimans et al. 2017]

(Miladinović et al. 2021)

SDN-VAE: Density Estimation

Type	Method	CIFAR-10	ImageNet32	CelebAHQ256
VAE-based	**SDN-VAE (ours)**	2.87	3.85	0.70
	IAF-VAE+ (ours)	3.05	4.00	0.71
	IAF-VAE (Kingma et al., 2016)	3.11	X	X
	BIVA (Maaløe et al., 2019)	3.08	X	X
	NVAE (Vahdat & Kautz, 2020)	2.91	3.92	0.70
Flow-based	GLOW (Kingma & Dhariwal, 2018)	3.35	4.09	1.03
	FLOW++ (Ho et al., 2019)	3.08	3.86	X
	ANF (Huang et al., 2020)	3.05	3.92	0.72
	SurVAE (Nielsen et al., 2020)	3.08	4.00	X
Autoregressive*	PixelRNN (Van Oord et al., 2016)	3.00	3.86	X
	PixelCNN (Van den Oord et al., 2016)	3.03	3.83	X
	PixelCNN++ (Salimans et al., 2017)	2.92	X	X
	PixelSNAIL (Chen et al., 2018)	**2.85**	3.80	X
	SPN (Menick & Kalchbrenner, 2018)	X	3.85	**0.61**
	IT (Parmar et al., 2018)	2.90	**3.77**	X

Negative test log-likelihood.

(Miladinović et al. 2021)

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CNN vs SDN

Negative test log-likelihood.

(Miladinović et al. 2021)

SDN-VAE: Density Estimation

SotA !!

CNN vs SDN

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Negative test log-likelihood.

(Miladinović et al. 2021)

SDN-VAE: Image Synthesis

temperature

temperature

(Miladinović et al. 2021)

SDN-VAE: Image Manipulation

Neighborhood exploration

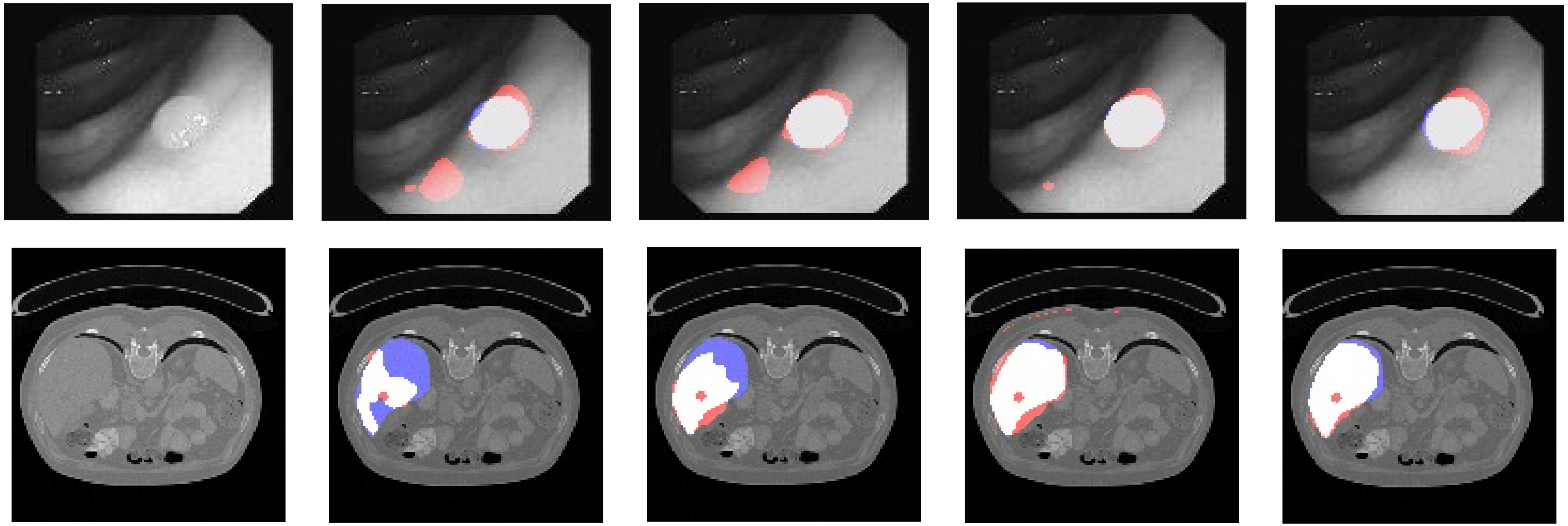
temperature

Interpolation

(Miladinović et al. 2021)

SDU-Nets for Medical Image Segmentation

SDN + U-Net [Carvalho et al. 2021]



Original **U-Net** **U-Net++** **SDN + U-Net** **SDN + U-Net++**

False Positives

False Negatives

Correct

(see the paper for quantitative results)

(Miladinović et al. 2021)

Implementation & Other Information

PyTorch

PyTorch Lightning

GitHub https://github.com/djordjemila/sdn

(PDT)

(Miladinović et al. 2021)

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img_decoder = nn.Sequential(
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    Conv2d(in_ch, out_ch, 4, 2, 1),
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    ...
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From CNN to SDN layer
in just one line of code !

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(PDT)

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arXiv link for the SDN paper: https://arxiv.org/abs/2103.08877

arXiv link for the follow-up, SDU-Net paper: https://arxiv.org/abs/2103.11713

Make sure you are up to date on Twitter ! Follow: https://twitter.com/djordjemila

Poster Session 4	May 4, 2021, 1 a.m.	May 4, 2021, 3 a.m.

(PDT)

(Miladinović et al. 2021)