FlexConv: Continuous Kernel Convolutions With Differentiable Kernel Sizes

David W. Romero*[1] Robert-Jan Bruintjes*[2]

* equal contribution

Jakub M. Tomczak[1] Erik J. Bekkers[3] Mark Hoogendoorn[1] Jan van Gemert[2]

1 VU VRIJE UNIVERSITEIT AMSTERDAM

2 TU Delft Delft University of Technology

3 Universiteit van Amsterdam

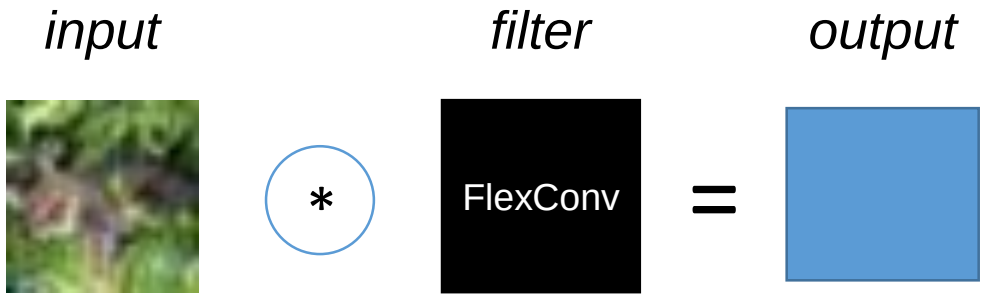
Abstract

FlexConv replaces convolutions

Contributions

1. Learns kernel size
2. High bandwidth kernel
3. Adaptable to data resolution

Learning kernel size



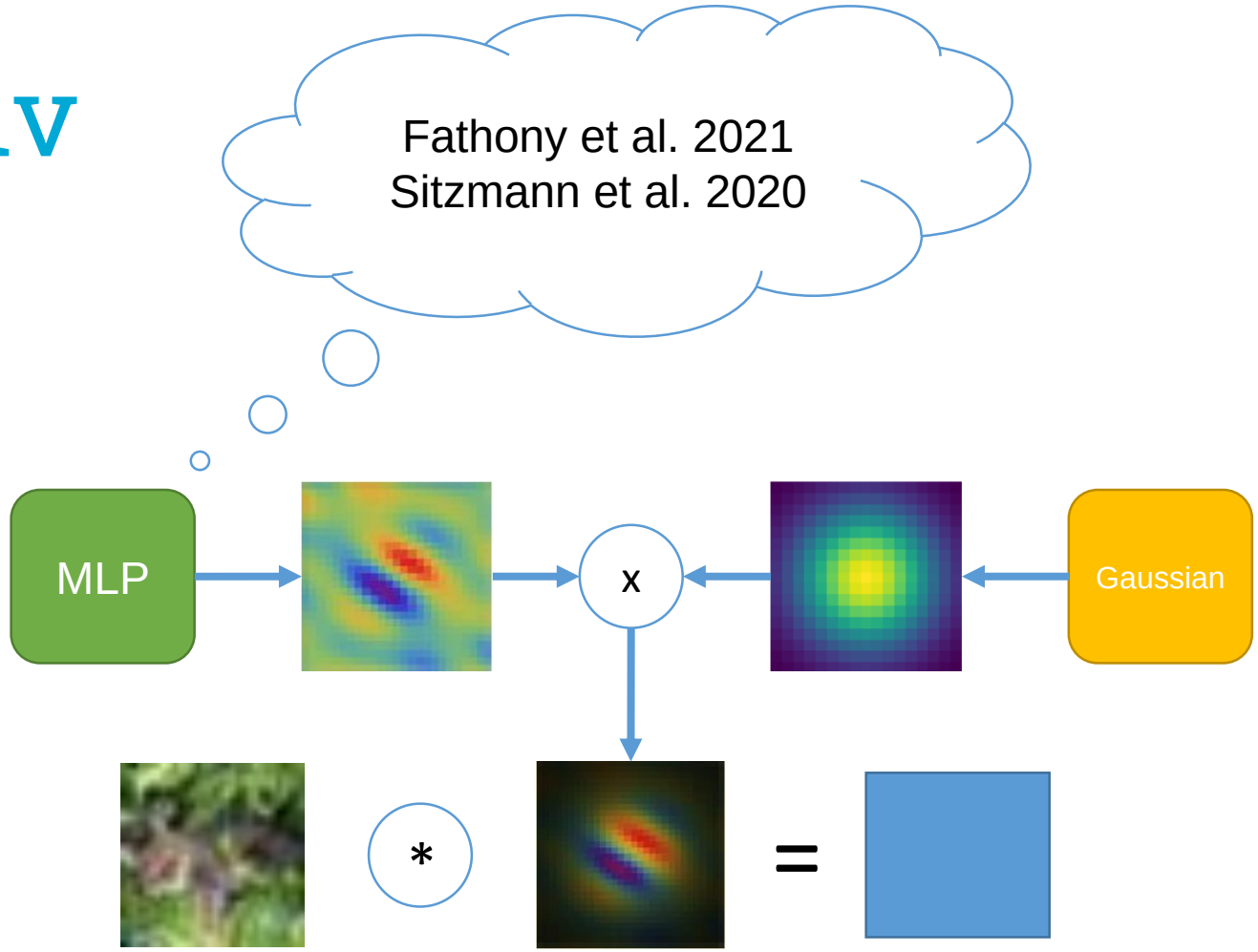
Pintea et al. 2021
Tomen et al. 2021

Silvia L Pintea, Nergis Tomen, Stanley F Goes, Marco Loog, and Jan C van Gemert. Resolution learning in deep convolutional networks using scale-space theory. arXiv preprint arXiv:2106.03412, 2021.

Nergis Tomen, Silvia-Laura Pintea, and Jan Van Gemert. Deep continuous networks. In Marina Meila and Tong Zhang (eds.), Proceedings of the 38th International Conference on Machine Learning, volume 139 of Proceedings of Machine Learning Research, pp. 10324–10335. PMLR, 18–24 Jul 2021.

Method

FlexConv



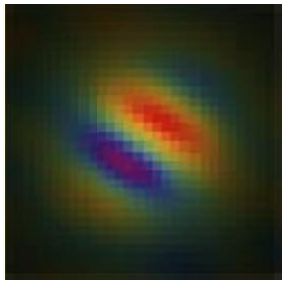
Rizal Fathony, Anit Kumar Sahu, Devin Willmott, and J Zico Kolter. Multiplicative filter networks. In International Conference on Learning Representations, 2021.

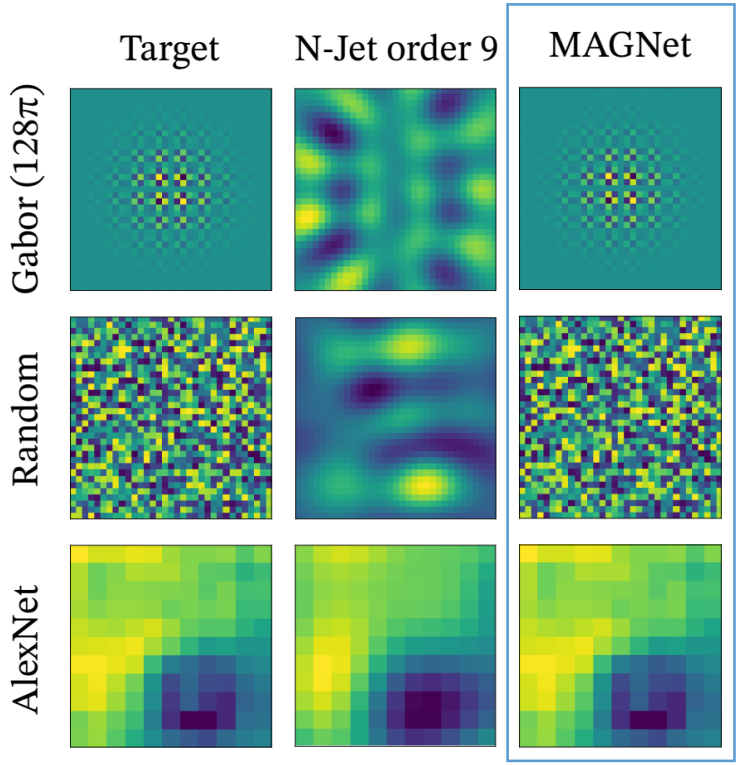
Vincent Sitzmann, Julien Martel, Alexander Bergman, David Lindell, and Gordon Wetzstein. Implicit neural representations with periodic activation functions. Advances in Neural Information Processing Systems, 33, 2020

High bandwidth kernels

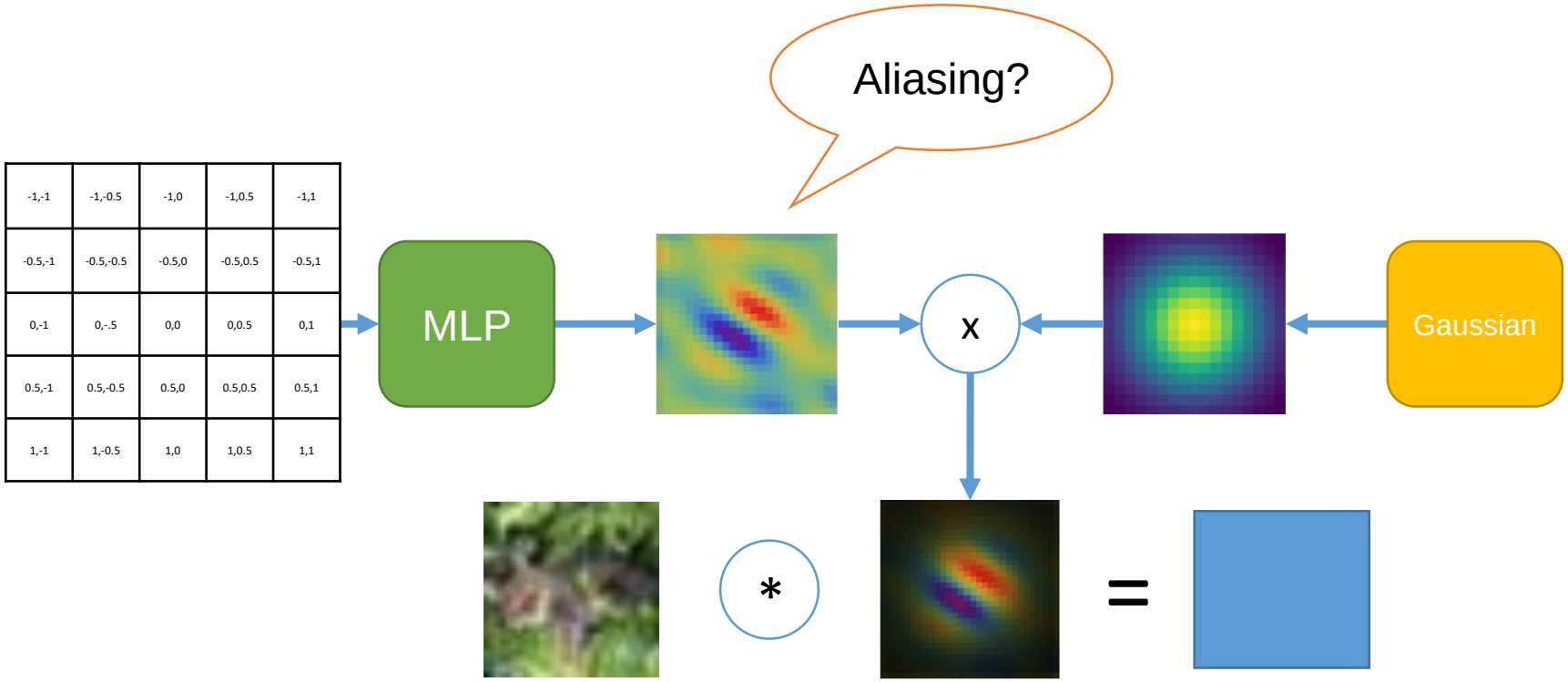
Related works

FlexConv

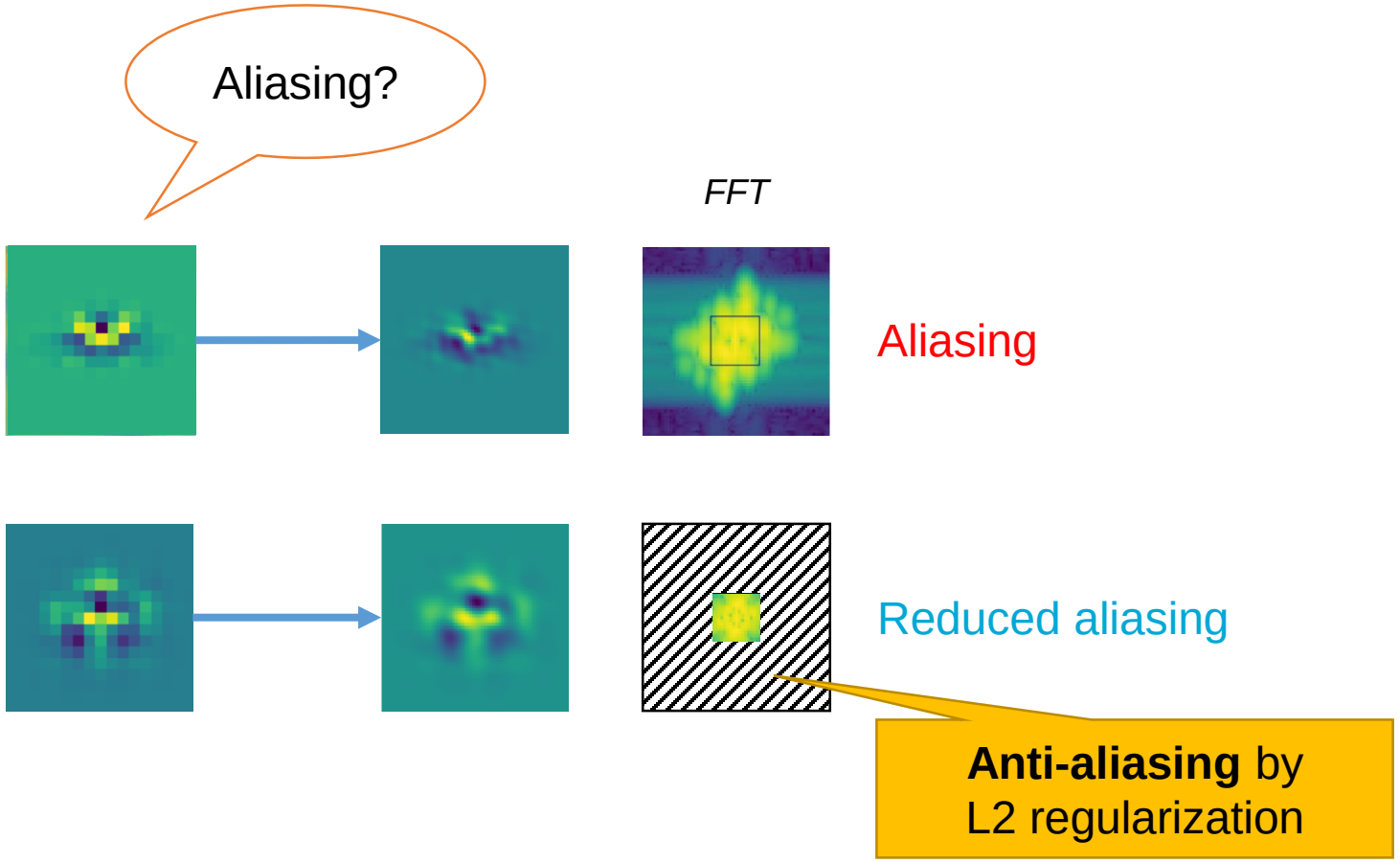




Adapting resolution



Adapting resolution



Results

Upscaled image classification

Model	Size	CIFAR-10 Acc. 16 px	Δ_{16px} 32 px
CIFARResNet-44	0.66M	85.8 ± 0.2	-31.6 ± 1.3
FlexNet-16 w/o reg.	0.67M	**86.4** ± 0.4	-34.4 ± 14.3
FlexNet-16 w/ reg. f^{+}_{MAGNet}	0.67M	**86.5** ± 0.1	-3.8 ± 2.0
FlexNet-16 w/ reg. f^{+}_{FlexConv}	0.67M	85.1 ± 0.3	**-3.3** ± 0.3

Sequence classification

Model	Size	CT	SC	SC_raw
GRU-ODE	89K	96.2	44.8	~10.0
GRU-Δt	89K	97.8	20.0	~10.0
GRU-D	89K	95.9	23.9	~10.0
ODE-RNN	89K	97.1	93.2	~10.0
NCDE	89K	98.8	88.5	~10.0
FlexTCN-2	105SK	**99.53**	**97.10**	**88.03**
FlexTCN-4	239K	**99.53**	**97.73**	**90.45**
FlexTCN-6	373K	**99.53**	**97.67**	**91.73**

Image classification

Model	Size	CIFAR-10 Acc.	Time (sec/epoch)
CIFARResNet-44	0.66M	92.9*†	22
DCN-σ^{ji}	0.47M	89.7 ± 0.3*	-
N-Jet-CIFARResNet32	0.52M	92.3 ± 0.3*	-
N-Jet-ALLCNN	1.07M	92.5 ± 0.1*	-
FlexNet-16	0.67M	92.2 ± 0.1	127

FlexConv: Continuous Kernel Convolutions With Differentiable Kernel Sizes

David W. Romero*[1] Robert-Jan Bruintjes*[2]

* equal contribution

Jakub M. Tomczak[1] Erik J. Bekkers[3] Mark Hoogendoorn[1] Jan van Gemert[2]

1 VU VRIJE UNIVERSITEIT AMSTERDAM

2 TU Delft Delft University of Technology

3 Universiteit van Amsterdam