UNIVERSITY OF REGINA

DEEP CONVOLUTIONAL SUM-PRODUCT NETWORKS

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OUTLINE

GENERATIVE MODELS
IN DEEP LEARNING

SUM-PRODUCT NETWORKS
(SPNs)

CONVOLUTIONAL NEURAL NETWORKS AS SPNs

CONVOLUTIONAL SPNs
(**CSPNs**)

OUTLINE

DEEP CONVOLUTIONAL SPNs (**DCSPNs**)

STATE-OF-THE-ART RESULTS

AND A FEW NICE SURPRISES

CONCLUSIONS

GENERATIVE MODELS IN DEEP LEARNING

GENERATIVE MODELS ARE OF CURRENT INTEREST

NADE

Larochelle and Murray

2011

VARIATIONAL AUTOENCODERS

Kingma and Welling

2014

GANs

Goodfellow et al.

2014

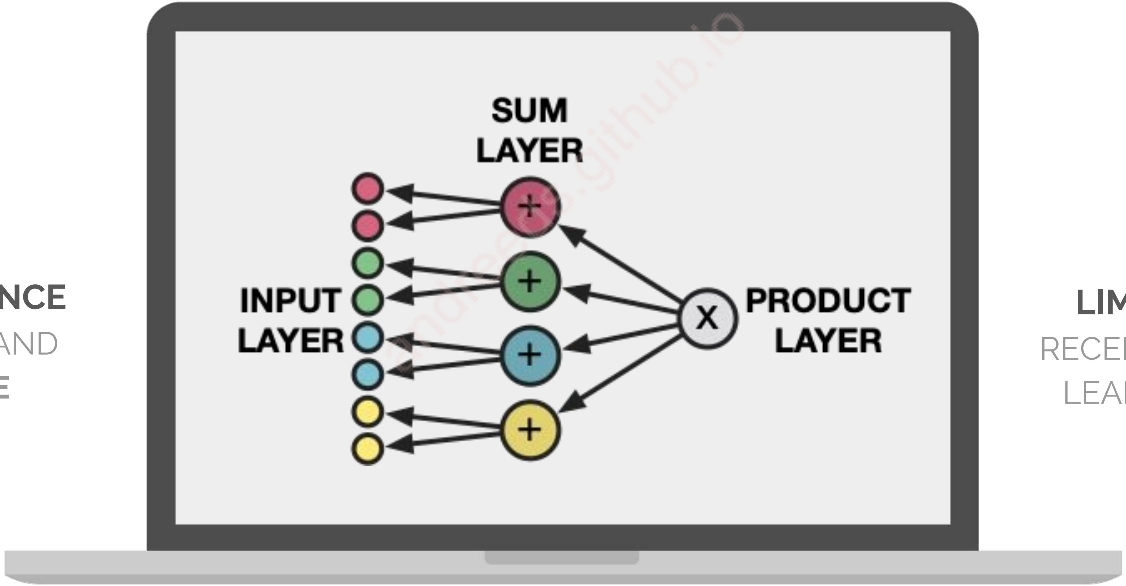
PIXEL RNN

Oord, Kalchbrenner, and Kavukcuoglu

2016

SUM-PRODUCT NETWORKS

GENERATIVE DEEP LEARNING MODEL

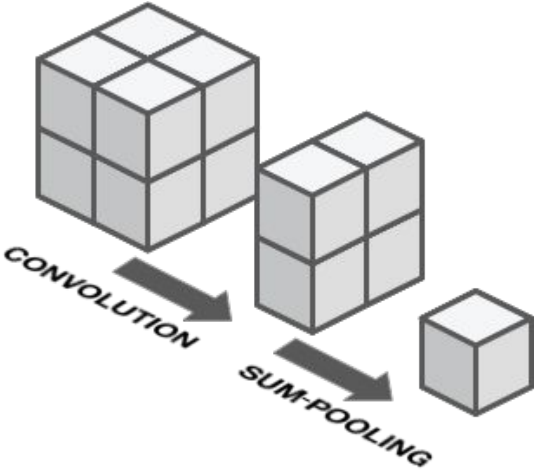


EFFICIENT INFERENCE
WHEN **COMPLETE** AND **DECOMPOSABLE**

LIMITED ATTENTION
RECEIVED FROM THE DEEP LEARNING COMMUNITY

Peharz et al.
2018

CONVOLUTIONAL NEURAL NETWORKS

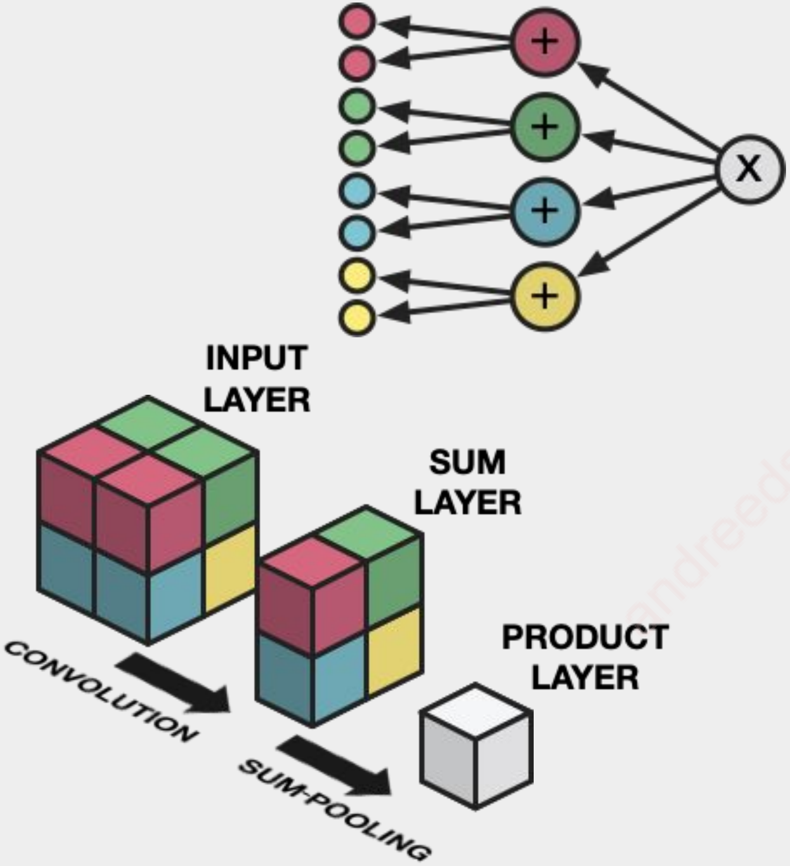


CONVOLUTIONAL LAYERS

NETWORK PARAMETERS ARE FILTERS

POOLING LAYERS

USES SLIDING WINDOWS



CNNs AS SPNs

CONVOLUTIONAL LAYERS

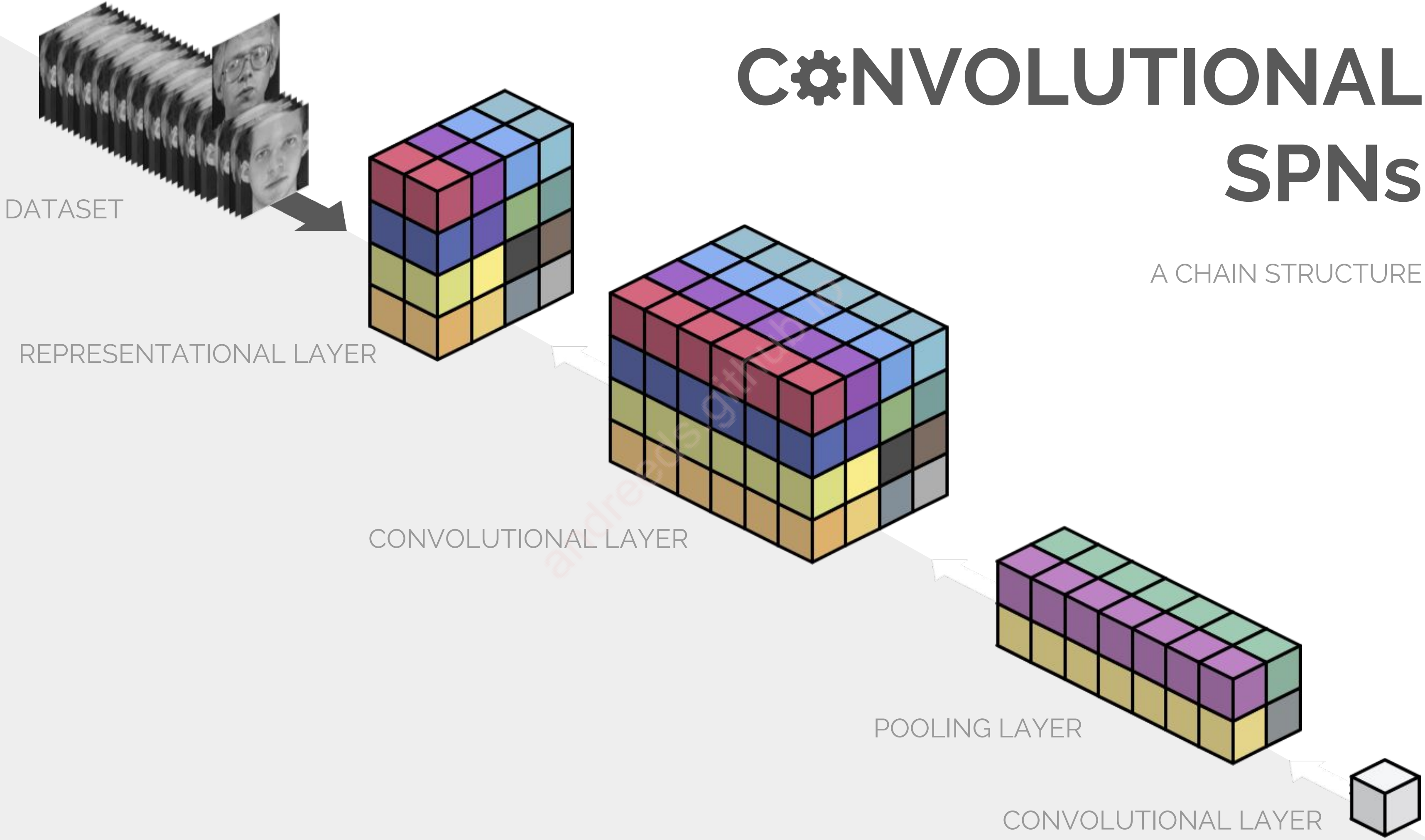
- FILTERS OF CERTAIN SIZES
- MAINTAINS **COMPLETENESS**

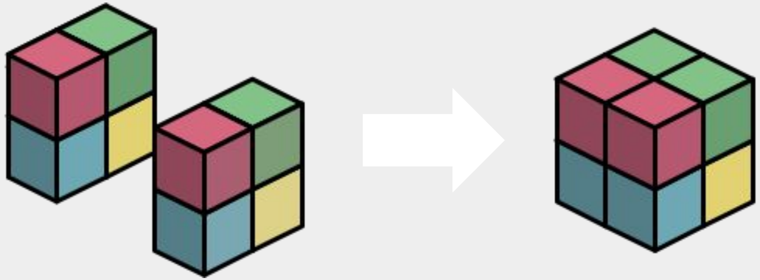
POOLING LAYERS

- NON-OVERLAPPING WINDOWS
- MAINTAINS **DECOMPOSABILITY**

CONVOLUTIONAL SPNs

A CHAIN STRUCTURE

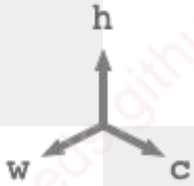




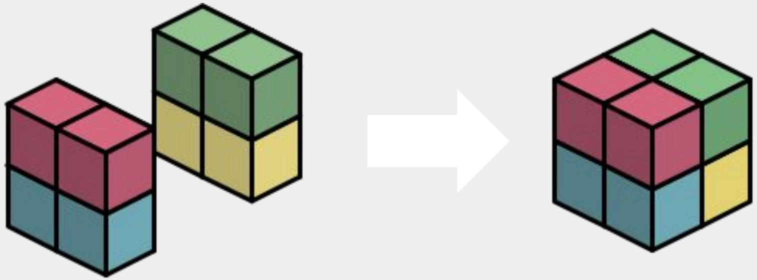
LAYERS (TENSORS) CAN BE AUGMENTED

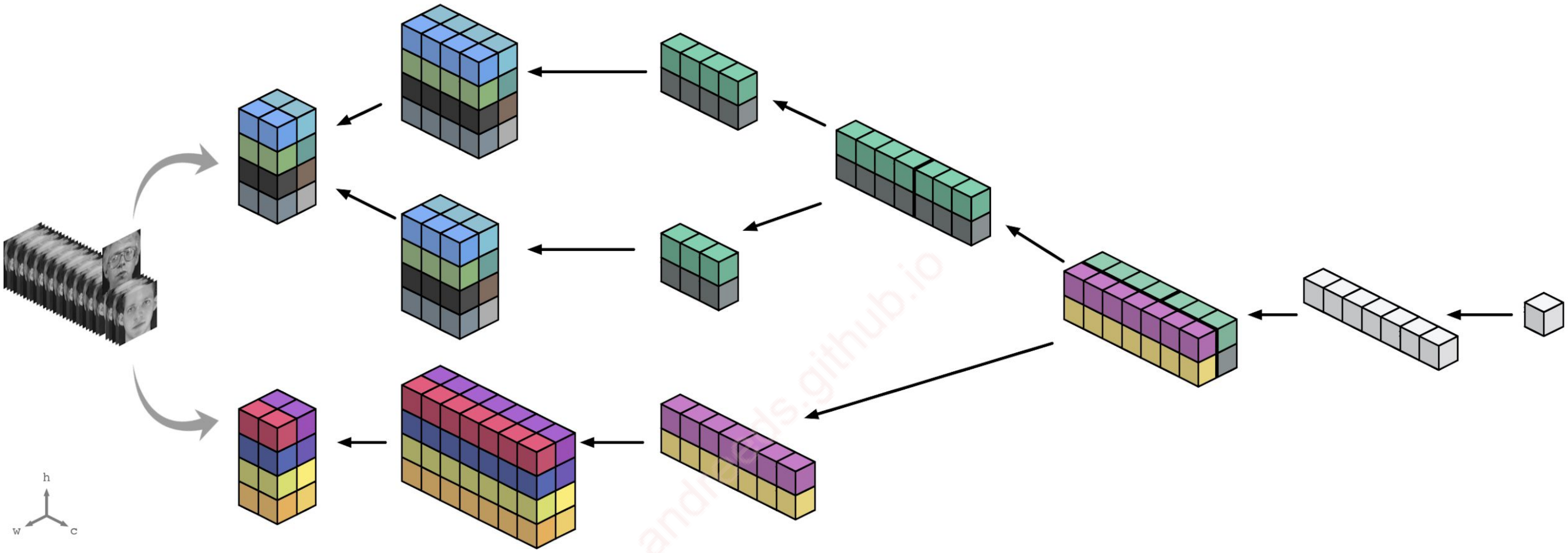
WHILE MAINTAINING

COMPLETENESS AND **DECOMPOSABILITY**



CREATING DEEPER STRUCTURES

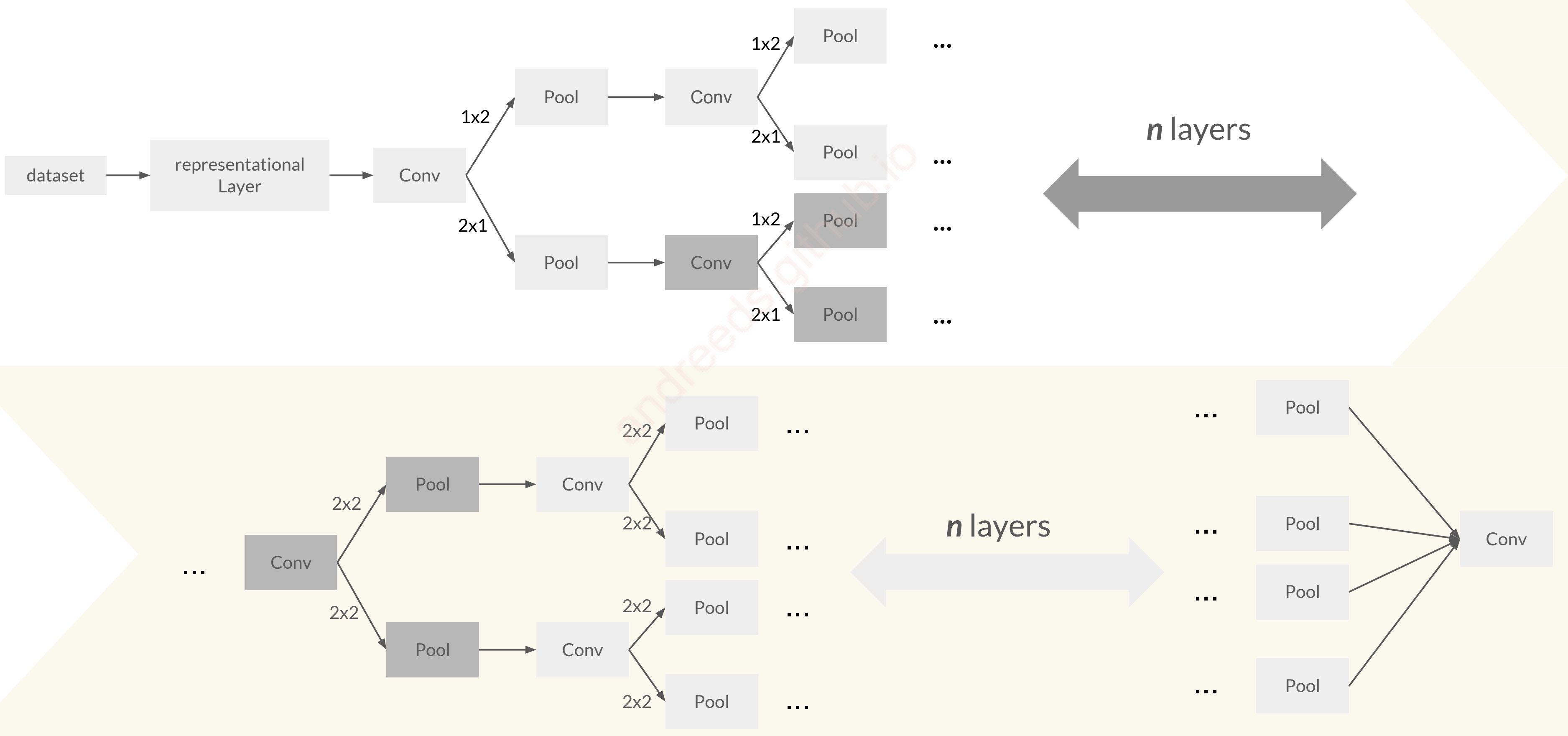




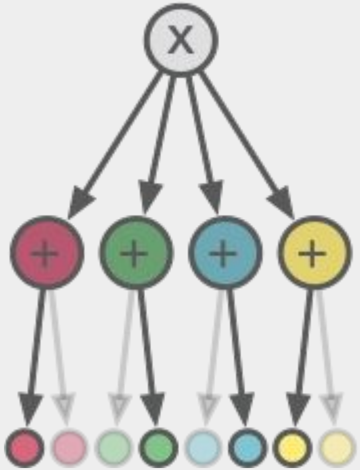
DEEP CONVOLUTIONAL SPNs

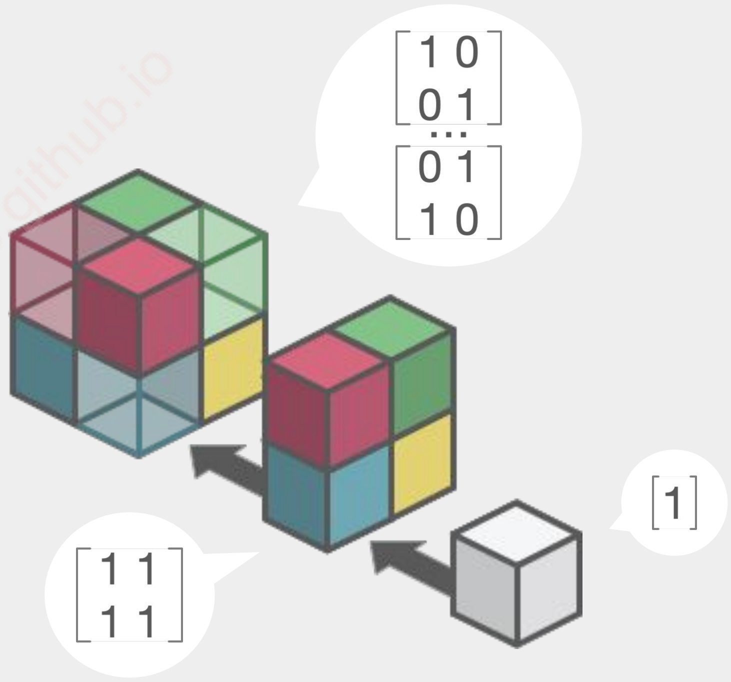
A RICH DAG OF CONVOLUTIONAL AND SUM-POOLING LAYERS

A WINNING STRUCTURE



VECTORIZED MPE

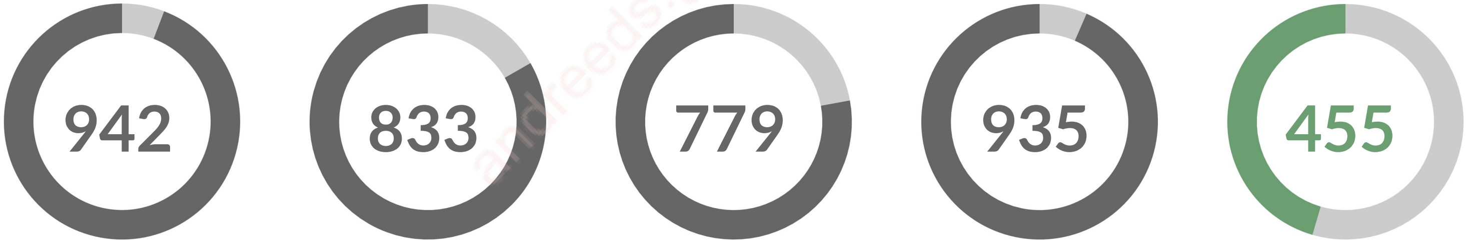




STATE-OF-THE-ART RESULTS IN OLIVETTI FACE

P&D	ICNN	D&V	DCGAN	DCSPN
Poon and Domingos 2011	*Amos, Xu, and Kolter* 2017	*Dennis and Ventura* 2012	*Yeh et al.* 2017	*Butz et al.* 2019

LEFT COMPLETION



STATE-OF-THE-ART RESULTS IN OLIVETTI FACE

	P&D	**ICNN**	**D&V**	**DCGAN**	**DCSPN**
	Poon and Domingos 2011	*Amos, Xu, and Kolter* 2017	*Dennis and Ventura* 2012	*Yeh et al.* 2017	*Butz et al.* 2019
LEFT COMPLETION	942	833	779	935	455
BOTTOM COMPLETION	918	-	782	707	503

STATE-OF-THE-ART RESULTS IN CALTECH

		P&D *Poon and Domingos* 2011	D&V *Dennis and Ventura* 2012	DCGAN *Yeh et al.* 2017	DCSPN *Butz et al.* 2019
LEFT COMPLETION	FACE	1815	1657	1334	**1178**
	DOLPHIN	3096	-	4096	**2002**
	HELICOPTER	2749	-	3925	**1702**
BOTTOM COMPLETION	FACE	1924	1517	**1046**	1149
	DOLPHIN	2767	-	4016	**2102**
	HELICOPTER	3064	-	3811	**2103**

OLIVETTI

LEFT COMPLETION

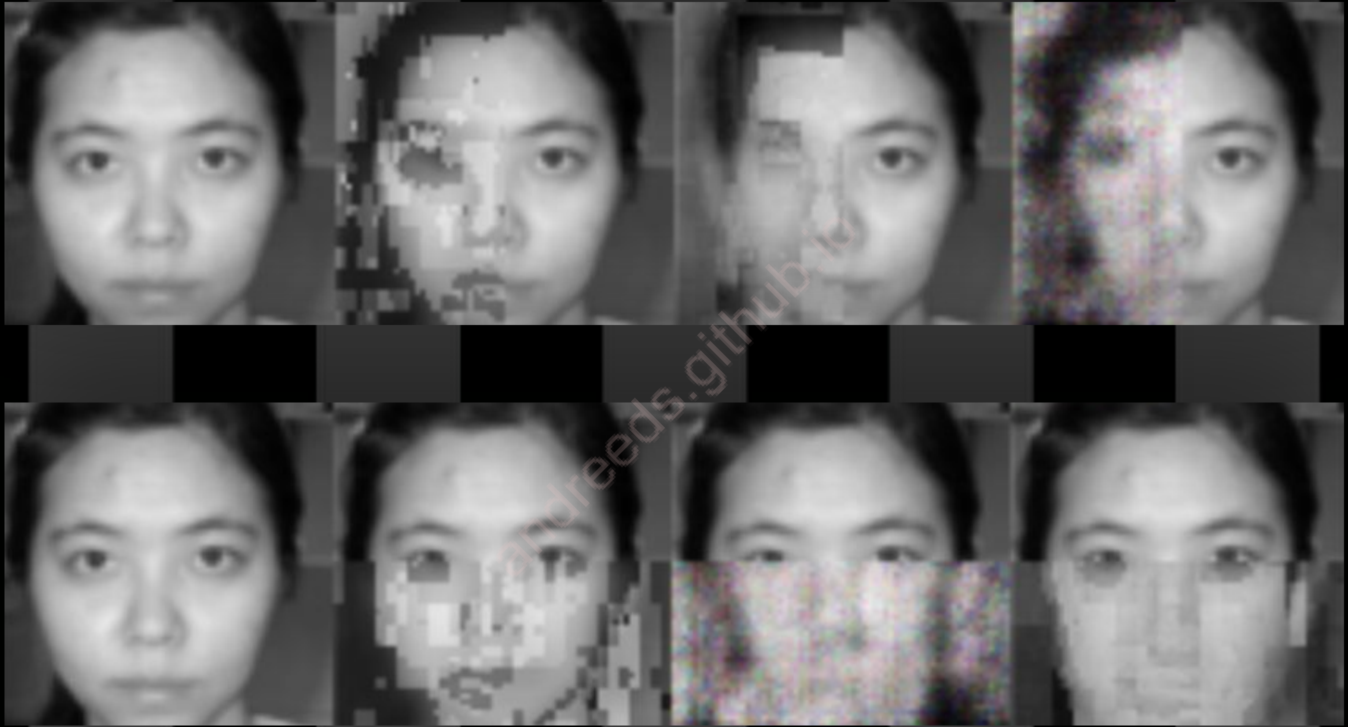
BOTTOM COMPLETION

ORIGINAL **DCSPN** **P&D** **GAN**

CALTECH

LEFT COMPLETION

BOTTOM COMPLETION



ORIGINAL **DCSPN** **P&D** **GAN**

AND A FEW NICE SURPRISES TOO

01 Learning DCSPNs with differentiable MPE

02 Relationship with GANs

03 Image sampling with variability

04 Good performance on a dataset with 65 images

LEARNING DCSPN WITH DIFFERENTIABLE MPE

MOTIVATED BY FUTURE WORK SUGGESTED IN

(Vergari et al., AAAI 2018)

LEARN DCSPNs USING DIFFERENTIABLE MPE

$$\min_{G} \max_{D} \mathbb{E}[log\ D(\mathbf{x})] + \mathbb{E}[log(1 - D(G(\mathbf{z})))]$$

DCSPNs yields an MSE score of 651

More promising than simply a low MSE score

RELATIONSHIP WITH GANs

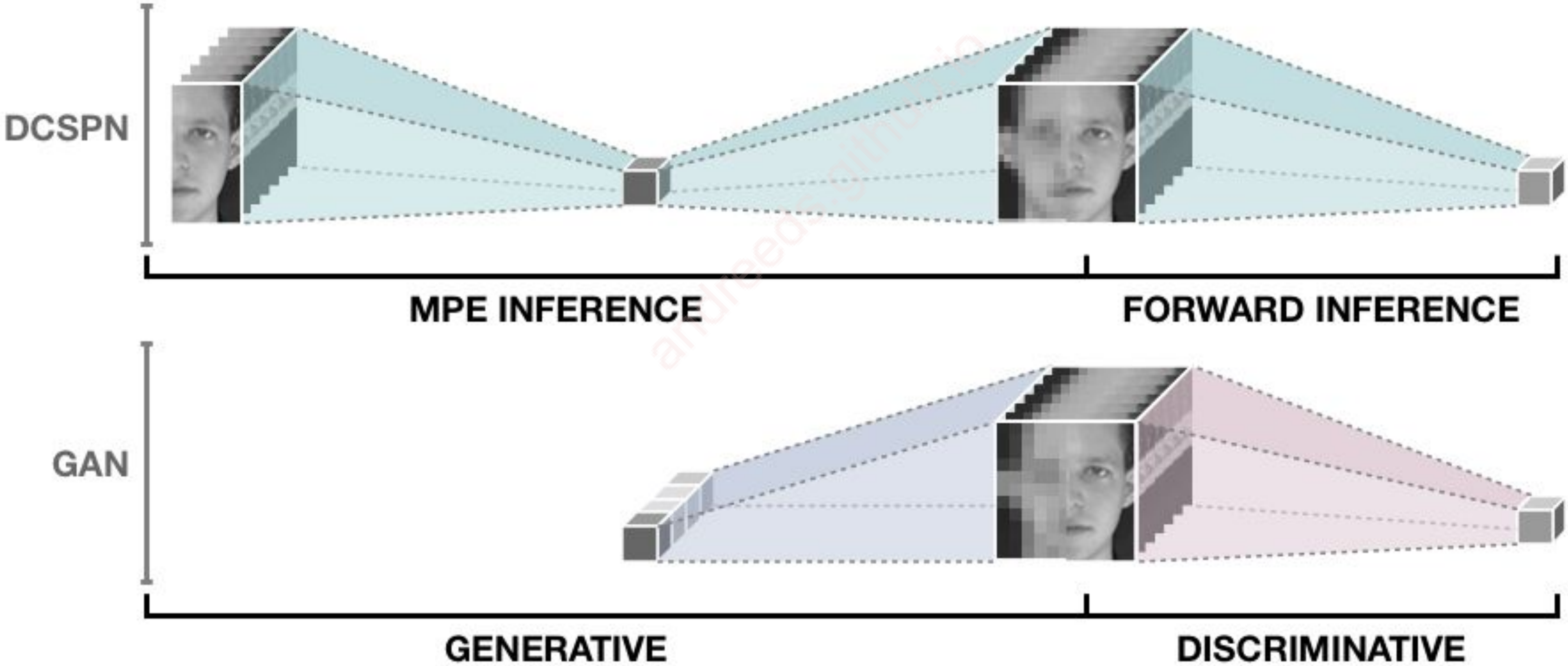


IMAGE SAMPLING

Simple modification in MPE Algorithm

DCSPN sampled images exhibit variability

GOOD PERFORMANCE ON A SMALL DATASET

ORIGINAL DCSPN P&D GAN

DCSPNs left-complete well on a small dataset

Caltech Dolphin contain 65 images

ANALYSIS

SMALL HORIZONTAL AND VERTICAL SUM-POOLING WINDOW SIZES CAN

- yield **deeper** structures
- leverage **local structure** in the image data

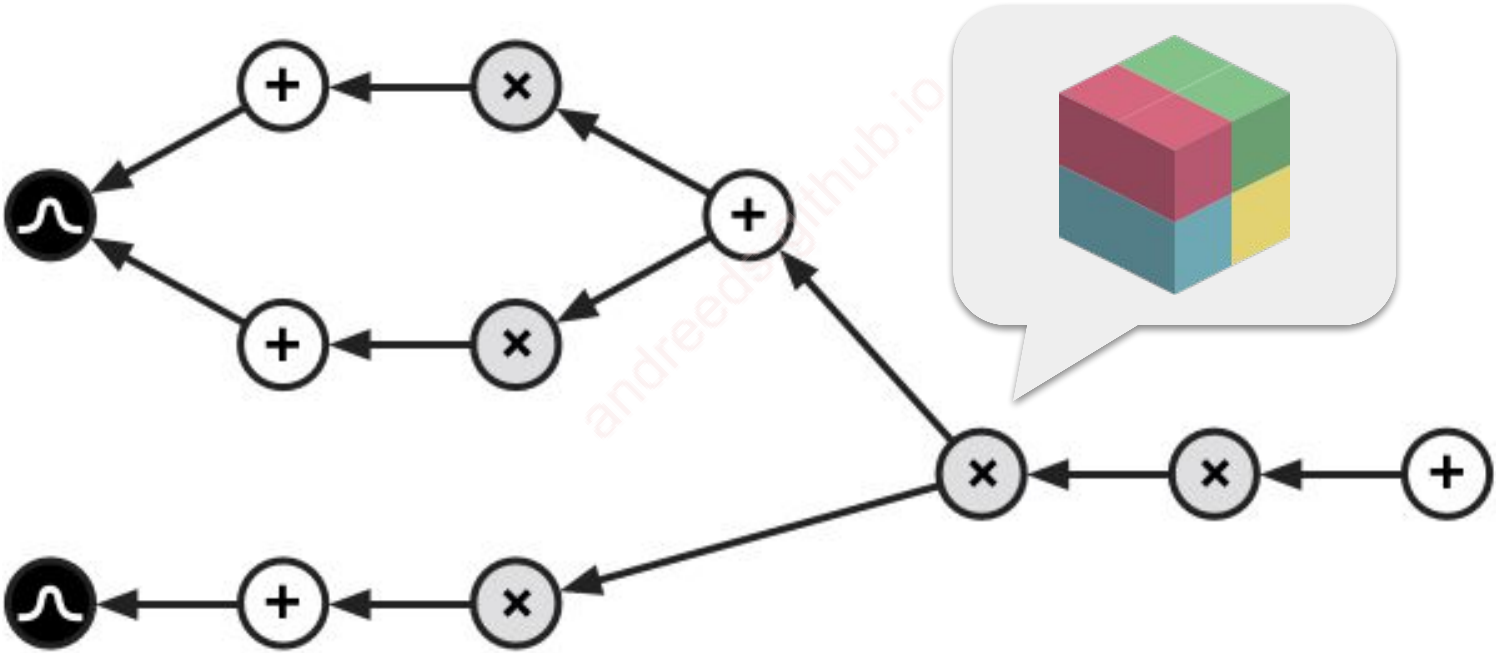
ALTERNATING SUM-POOLING WINDOW SIZES CAN

- serve as a **regularization** technique
- alleviate **vanishing gradient**

TWO FILTER SIZE OPTIONS ALLOWS FOR

controlling trade-off between quality and size

FUTURE WORK



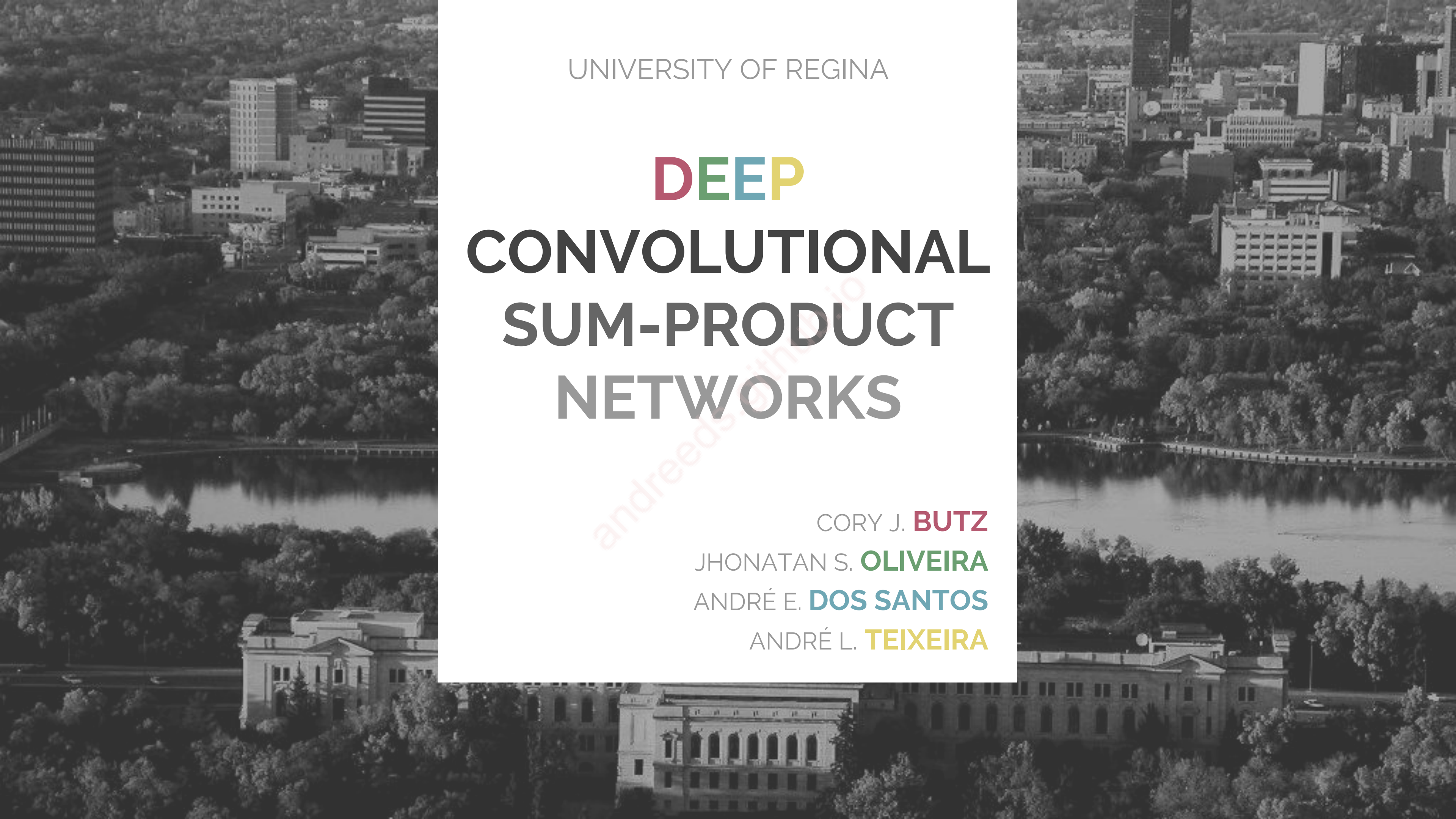
CONCLUSION

WE ESTABLISH WHEN SUBCLASSES OF CNNs DEFINE SPNs

DCSPNs ARE CNNs WHICH ALSO CAN TAKE ADVANTAGE OF KNOWN TECHNIQUES IN PROBABILISTIC GRAPHICAL MODELS

SEVERAL STATE-OF-THE-ART MSE SCORES IN IMAGE COMPLETION

AND NICE SURPRISES INCLUDING VARIABILITY IN IMAGE SAMPLING AND AN INTRIGUING RELATIONSHIP WITH GAN



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