

# Histogram Layer for Texture Classification

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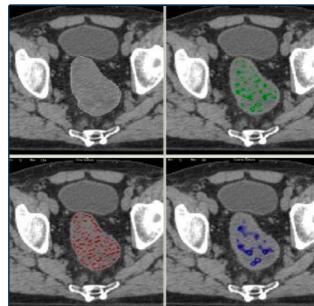


## Texture Classification

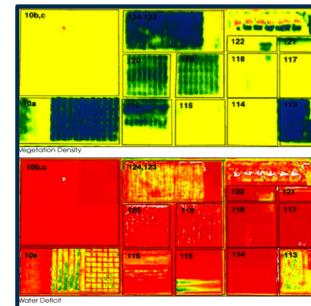
- **Definition:** an area of texture analysis that focuses on assigning images into a texture classes.



### Applications



Medical Imaging



Agriculture



Autonomous Vehicles



# Previous Approaches

## Traditional Approach

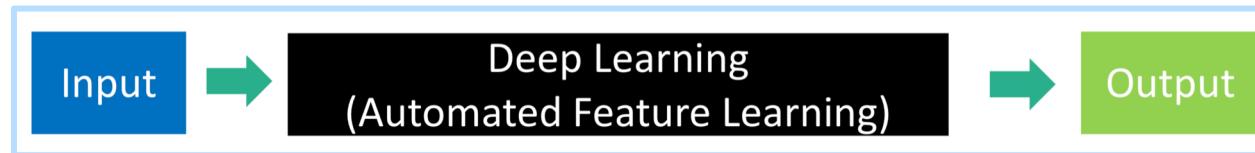


Does not necessarily need a lot of data;  
The features are more explainable;



Very laborious; often needed to determine  
features empirically

## Deep Learning Approach



Automated feature learning;  
not very laborious



Requires copious amount of labeled data along with  
immense amount of computational power



## *Goal of Research*

Traditional  
Approach



Deep Learning  
Approach

We propose a novel model that incorporates a localized histogram layer to convolutional neural networks for texture classification.



# Standard Histogram Operation

$$y_k = \begin{cases} 1, & B_k - w \leq x_k < B_k + w \\ 0, & \text{otherwise} \end{cases}$$

Standard Operation

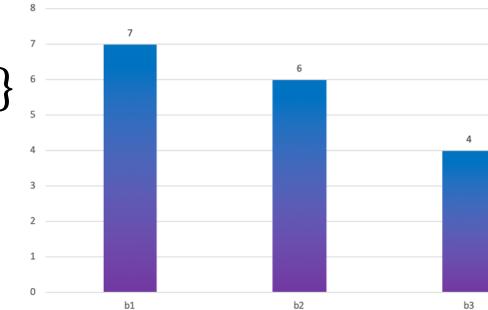
$$\begin{aligned} B_k (\text{bin center}) &= \{1, 2, 3\} \\ \omega (\text{bin width}) &= \{0, 0, 0\} \end{aligned}$$

1	3	2	2
3	1	2	1
1	2	1	3
2	2	1	1

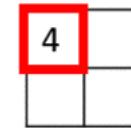


4 x 4 Image

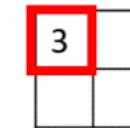
Standard Histogram Operation



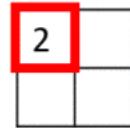
Bin 1



Bin 2



Bin 3



2 x 2 x 3 Feature Maps

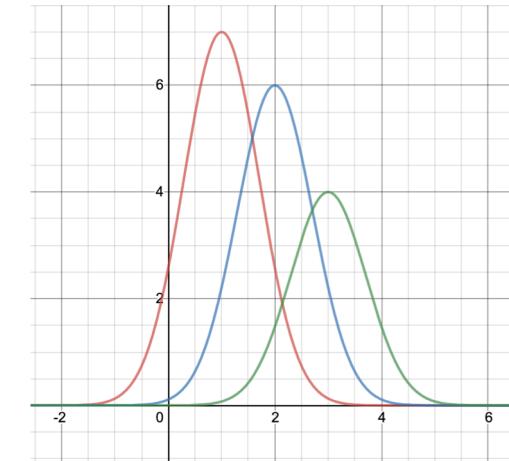


# Radial Basis Functions (RBFs)

$$y_k = \frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N e^{-\frac{(x_{ij} - \mu_k)^2}{\sigma_k^2}}.$$

Radial Basis Function

$\mu_k$  (bin center) = {1,2,3}  
 $\sigma_k$  (bin width) = {1,1,1}  
 $x_{ij}$  (feature map value)



## What's different?

1. Soft binning assignments
2. Differentiable

1	3	2	2
3	1	2	1
1	2	1	3
2	2	1	1

4 x 4 Image

4 x 4 Image

Bin 1

5.14

Bin 2

5.21

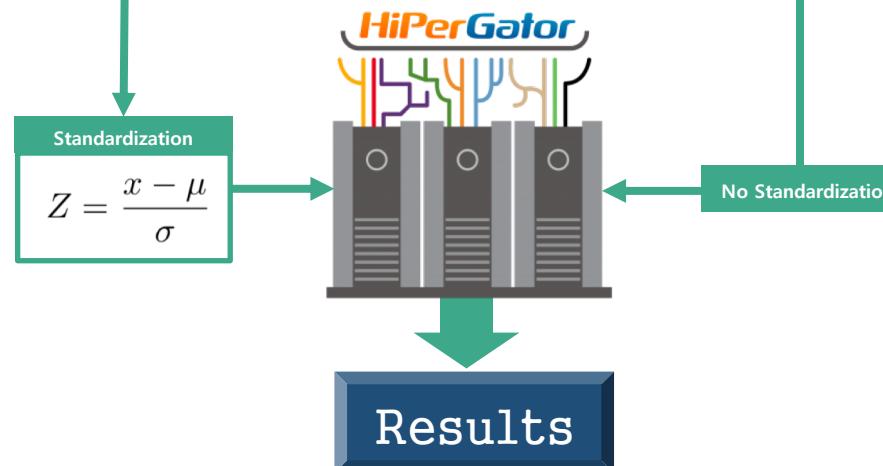
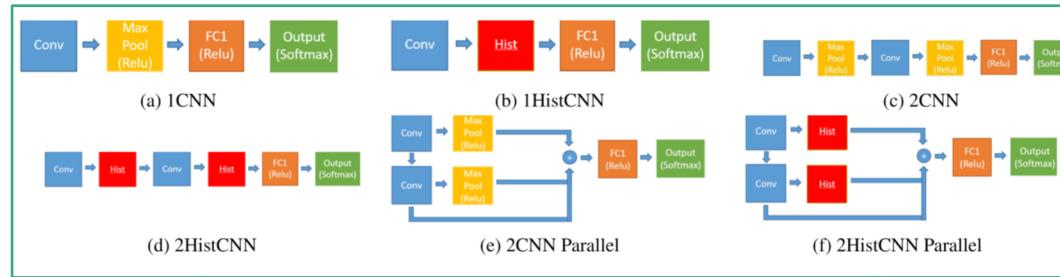
Bin 3

3.18

2 x 2 x 3 Feature Maps



# Experiment Setup





# Result: Standardized vs Non-Standardized

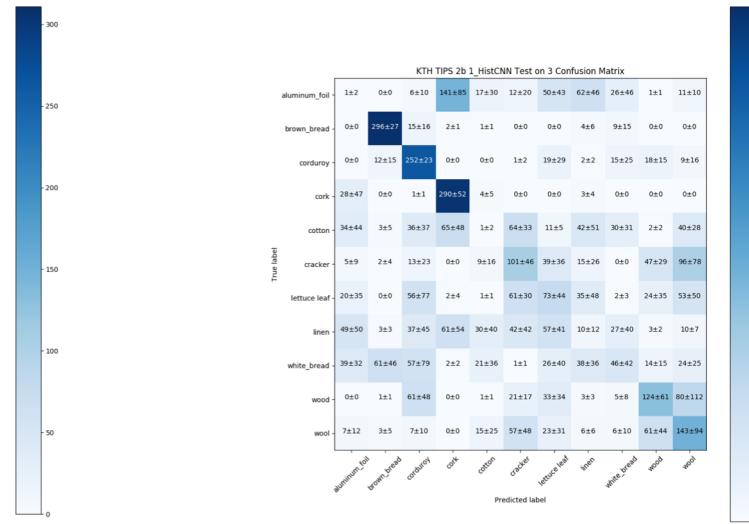
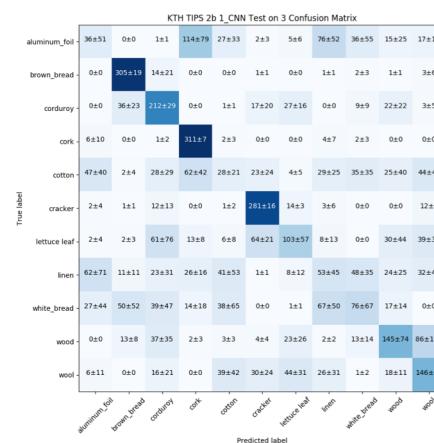
Average Overall Accuracy

Network	Average Overall Accuracy	
	Non-Standardized	Standardized
1_CNN	$38.87 \pm 4.05$	$47.48 \pm 0.97$
1_HistCNN	$34.90 \pm 4.09$	$37.43 \pm 3.33$
2_CNN	$29.51 \pm 5.14$	$44.35 \pm 1.07$
2_HistCNN	$36.75 \pm 2.58$	$40.14 \pm 1.49$
2_CNN_parallel	$40.31 \pm 3.79$	$47.66 \pm 1.22$
2_HistCNN_parallel	$35.91 \pm 4.15$	$38.20 \pm 2.85$

Every network improved performance significantly with standardization, averaging about 6.50% increase in average overall accuracy



# Result: 1CNN vs 1HistCNN

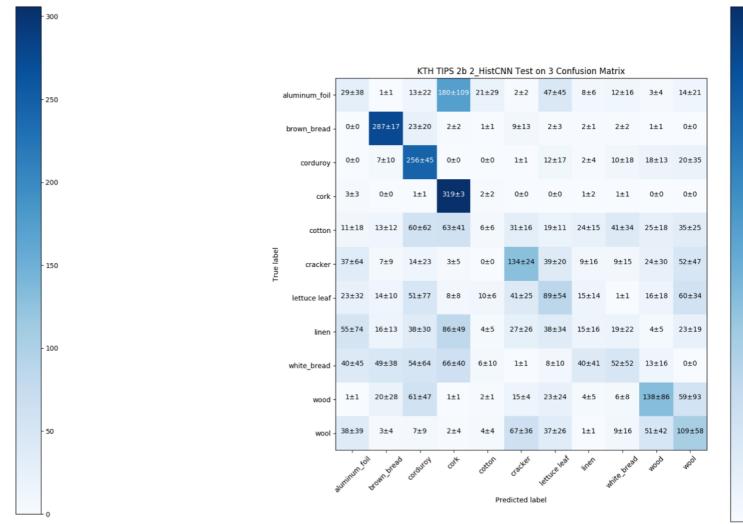
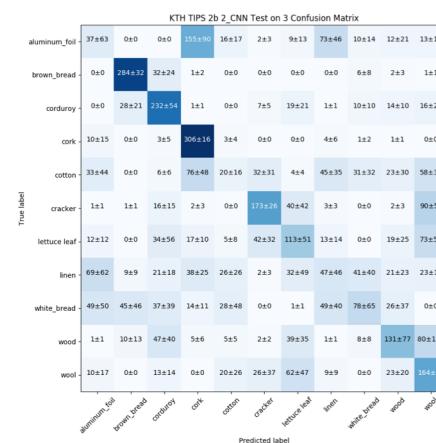


1\_CNN &amp; 1\_HistCNN

	1_CNN Avg. F1-score	1_HistCNN Avg. F1-score	1_CNN Avg. Precision	1_HistCNN Avg. Precision	1_CNN Avg. Recall	1_HistCNN Avg. Recall
Sample A	$0.45 \pm 0.24$	$0.31 \pm 0.28$	$0.47 \pm 0.22$	$0.30 \pm 0.27$	$0.48 \pm 0.29$	$0.36 \pm 0.32$
Sample B	$0.43 \pm 0.22$	$0.35 \pm 0.29$	$0.43 \pm 0.21$	$0.33 \pm 0.30$	$0.47 \pm 0.27$	$0.40 \pm 0.32$
Sample C	$0.44 \pm 0.25$	$0.28 \pm 0.28$	$0.43 \pm 0.24$	$0.29 \pm 0.31$	$0.49 \pm 0.28$	$0.33 \pm 0.33$
Sample D	$0.40 \pm 0.23$	$0.35 \pm 0.30$	$0.42 \pm 0.22$	$0.35 \pm 0.29$	$0.46 \pm 0.29$	$0.41 \pm 0.32$



# Result: 2CNN vs 2HistCNN

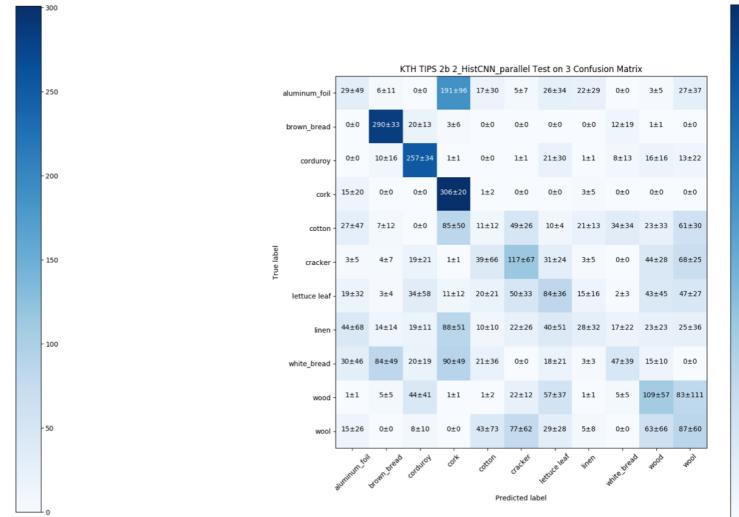
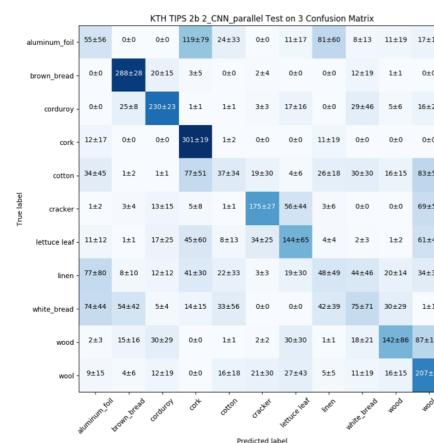


2\_CNN & 2\_HistCNN

	2_CNN Avg. F1-score	2_HistCNN Avg. F1-score	2_CNN Avg. Precision	2_HistCNN Avg. Precision	2_CNN Avg. Recall	2_HistCNN Avg. Recall
Sample A	$0.40 \pm 0.23$	$0.33 \pm 0.25$	$0.41 \pm 0.22$	$0.31 \pm 0.21$	$0.44 \pm 0.28$	$0.41 \pm 0.33$
Sample B	$0.40 \pm 0.23$	$0.37 \pm 0.24$	$0.40 \pm 0.21$	$0.37 \pm 0.24$	$0.44 \pm 0.26$	$0.42 \pm 0.31$
Sample C	$0.42 \pm 0.22$	$0.34 \pm 0.25$	$0.44 \pm 0.22$	$0.34 \pm 0.22$	$0.46 \pm 0.29$	$0.40 \pm 0.34$
Sample D	$0.38 \pm 0.24$	$0.32 \pm 0.24$	$0.40 \pm 0.24$	$0.31 \pm 0.22$	$0.43 \pm 0.27$	$0.38 \pm 0.32$



# Result: 2CNN\_parallel vs 2HistCNN\_parallel



2\_CNN\_parallel & 2\_HistCNN\_parallel

	2_CNN-par Avg. F1-score	2_HistCNN-par Avg. F1-score	2_CNN-par Avg. Precision	2_HistCNN-par Avg. Precision	2_CNN-par Avg. Recall	2_HistCNN-par Avg. Recall
Sample A	$0.44 \pm 0.26$	$0.31 \pm 0.26$	$0.45 \pm 0.24$	$0.31 \pm 0.31$	$0.48 \pm 0.31$	$0.36 \pm 0.31$
Sample B	$0.44 \pm 0.24$	$0.31 \pm 0.27$	$0.48 \pm 0.23$	$0.31 \pm 0.30$	$0.46 \pm 0.30$	$0.36 \pm 0.30$
Sample C	$0.45 \pm 0.24$	$0.38 \pm 0.25$	$0.46 \pm 0.24$	$0.39 \pm 0.30$	$0.49 \pm 0.32$	$0.43 \pm 0.30$
Sample D	$0.42 \pm 0.28$	$0.31 \pm 0.26$	$0.43 \pm 0.24$	$0.35 \pm 0.31$	$0.48 \pm 0.33$	$0.38 \pm 0.30$



# Conclusion

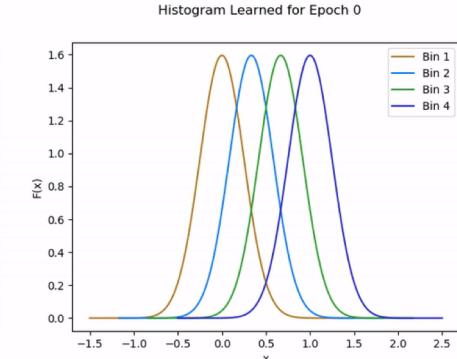
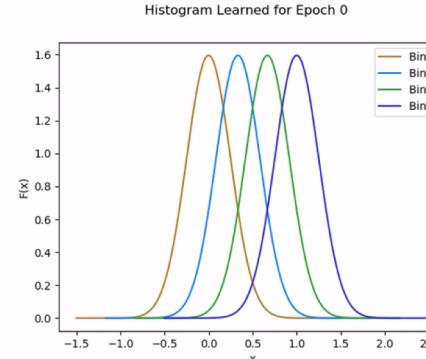
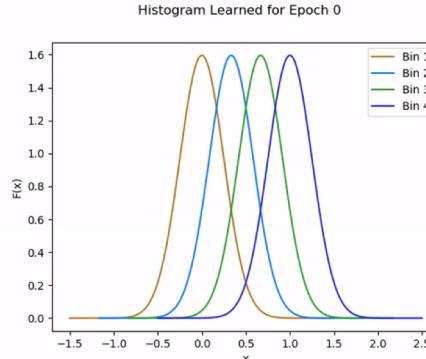
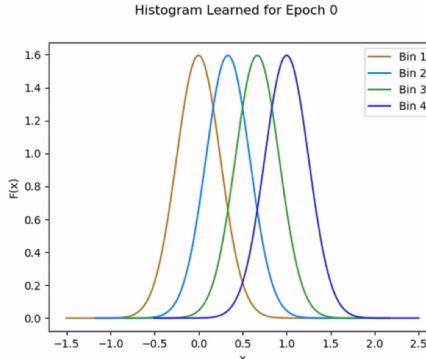
## Contributions

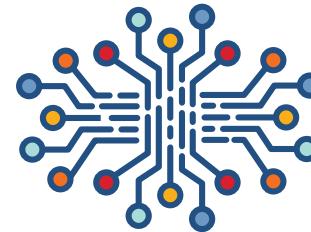
1. Learned standardization improves performance significantly.
2. Histogram layer did not necessarily have a better performance overall, but they performed better than the standard CNNs on some classes

## Future Works

1. Different initialization techniques for histogram layer can be used
2. Tuning of parameters (i.e. window size, number of bins, kernel size)

Histogram Learned for 1\_HistCNN (Non-standardized, 0-50 epochs)



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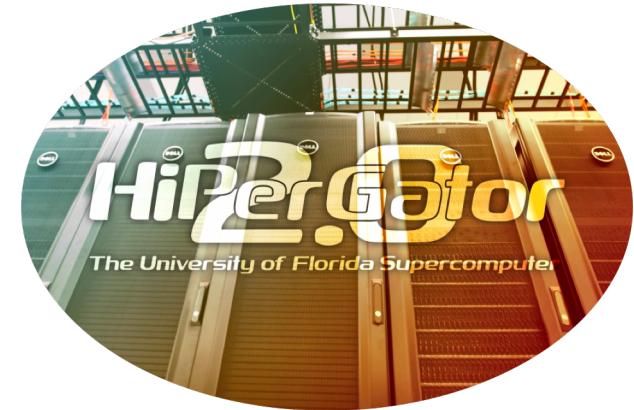
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# References

- KTH Texture: <https://images.app.goo.gl/r3V3XEnE8TxyqYrd7>
- Medical Imaging: <https://images.app.goo.gl/K5GRT1XHSCcyf7bA7>
- Agriculture: <https://images.app.goo.gl/kAPFDa7q7jVcsvMn9>
- Autonomous Vehicles: <https://www.mdpi.com/1424-8220/19/9/2064/htm>
- HiPerGator: <https://www.rc.ufl.edu/services/hipergator/>
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