Wavelet Convolutional Neural Networks for Texture Classification

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Texture

- Преимущественная ориентация элементов, составляющих материал
- Нет информации о форме объекта

Classification approaches

- Conventional Texture Descriptors
- Convolutional Neural Networks
- Spectral Approaches

Haar Wavelets

The Haar scaling function is defined as

$$\phi(x) = \begin{cases} 1, & \text{if } 0 \le x < 1 \\ 0, & \text{otherwise.} \end{cases}$$

The Haar Wavelet's mother function is defined as $\psi(x) = \phi(2x) - \phi(2x-1)$

$$\psi(x) = \begin{cases} 1, & 0 \le x < 1/2, \\ -1, & 1/2 \le x < 1, \\ 0, & \text{otherwise.} \end{cases}$$

Haar Wavelet's properties:

(1) Any function can be the linear combination of

$\phi(x), \phi(2x), \phi(2^2 x), \cdots \phi(2^k x), \cdots$ and their shifting functions

(2) Any function can be the linear combination of constant function,

$\psi(x), \psi(2x), \psi(2^2 x), \cdots, \psi(2^k x), \cdots$ and their shifting functions

(3) The set of functions $\{2^{j/2}\phi(2^j x - k); k \in Z\}$ is an orthonormal basis.

Haar Wavelets

How to do Haar transform:

Assumption: 1D signal f of the length $N = 2^n$

1-level Haar-Transform for $f = (x_1, x_2, \ldots, x_N)$

$$f \xrightarrow{H_1} (a^1 \mid d^1)$$

where

$$a^1 = \left(\frac{x_1 + x_2}{\sqrt{2}}, \frac{x_3 + x_4}{\sqrt{2}}, \cdots, \frac{x_{N-1} + x_N}{\sqrt{2}}\right)$$

$$d^1 = \left(\frac{x_1 - x_2}{\sqrt{2}}, \frac{x_3 - x_4}{\sqrt{2}}, \cdots, \frac{x_{N-1} - x_N}{\sqrt{2}}\right)$$

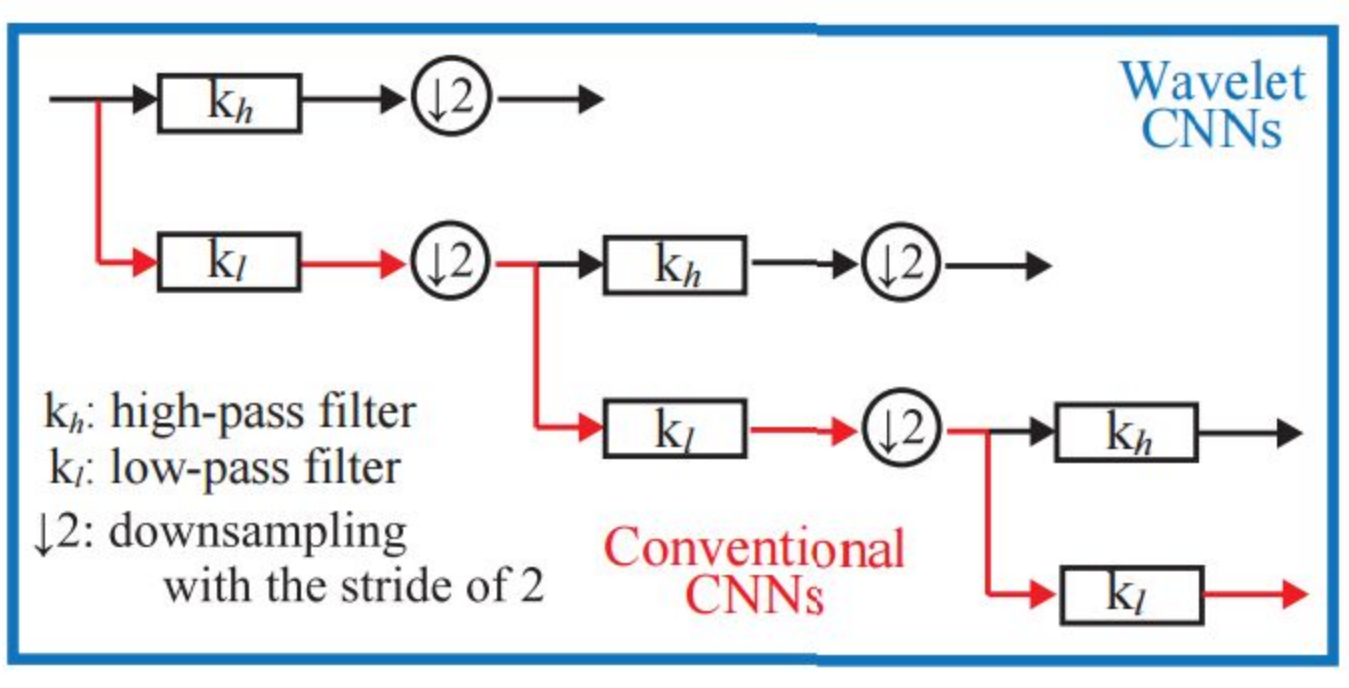
Wavelet CNN

$$\mathbf{y} = (\mathbf{x} * \mathbf{k}) \downarrow p$$

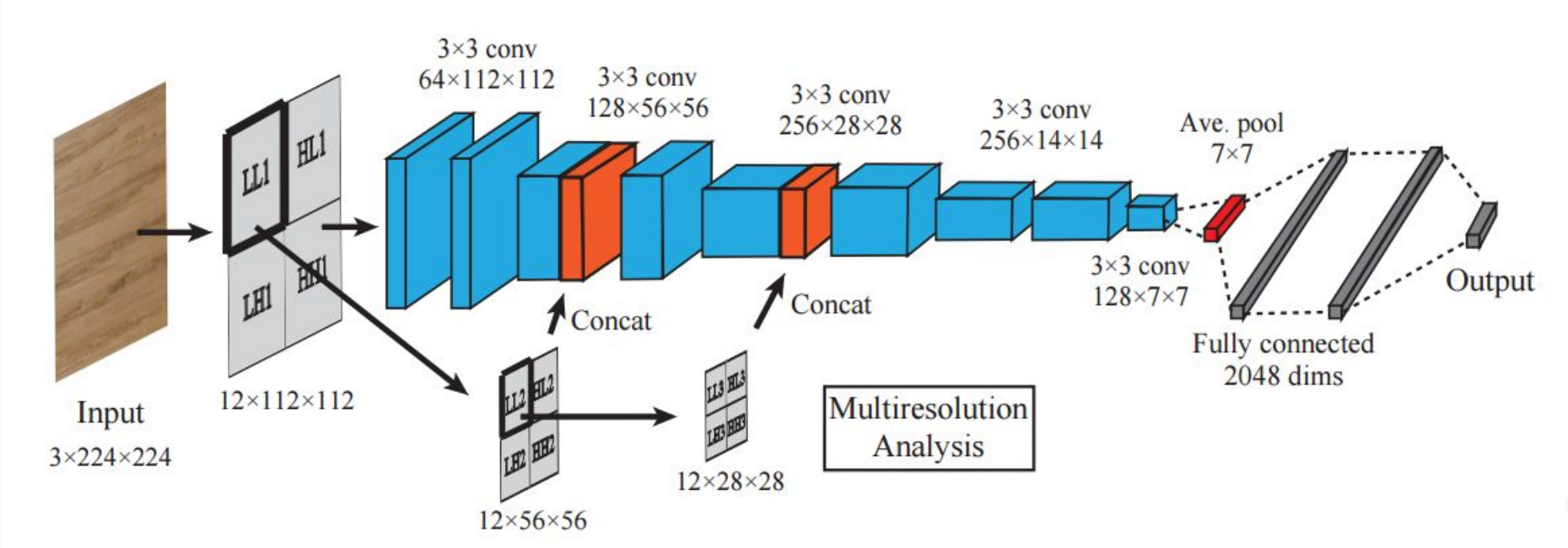
$$\mathbf{x}_{\text{low}} = (\mathbf{x} * \mathbf{k}_l) \downarrow 2$$
$$\mathbf{x}_{\text{high}} = (\mathbf{x} * \mathbf{k}_h) \downarrow 2$$

$$\mathbf{x}_{\text{low},l+1} = (\mathbf{x}_{\text{low},l} * \mathbf{k}_l) \downarrow 2$$
$$\mathbf{x}_{\text{high},l+1} = (\mathbf{x}_{\text{low},l} * \mathbf{k}_h) \downarrow 2$$

Wavelet CNN


Wavelet CNNs
k_h
↓2
k_l
↓2
k_h
↓2
k_l
↓2
k_h
k_l
k_h: high-pass filter
k_l: low-pass filter
↓2: downsampling with the stride of 2
Conventional CNNs

Wavelet CNN


3×3 conv
64×112×112
3×3 conv
128×56×56
3×3 conv
256×28×28
3×3 conv
256×14×14
Ave. pool
7×7
3×3 conv
128×7×7
Fully connected
2048 dims
Output
Concat
Concat
LL1
HL1
LH1
HH1
Input
3×224×224
12×112×112
LL2
HL2
LH2
HH2
12×56×56
LL3
HL3
LH3
HH3
12×28×28
Multiresolution
Analysis

Results

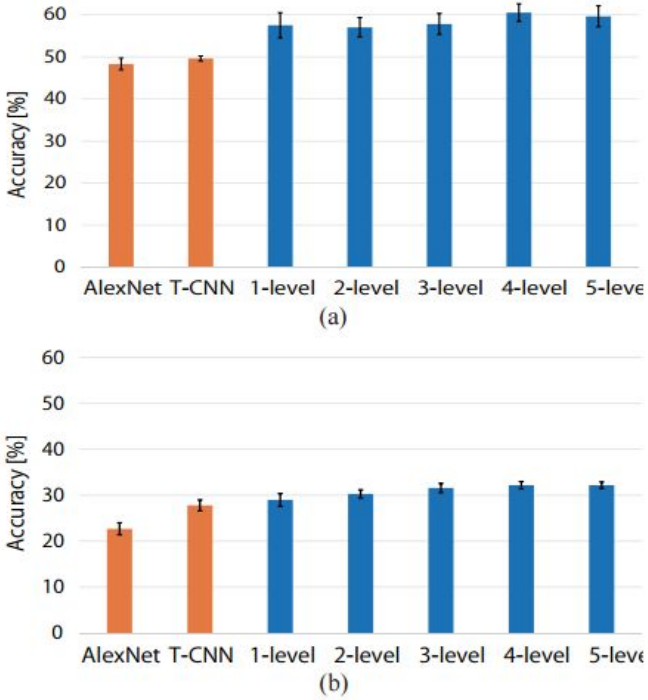


Figure 4. Classification results of (a) kth-tips2-b and (b) DTD for networks trained from scratch. We compared our models (blue) with AlexNet and T-CNN.

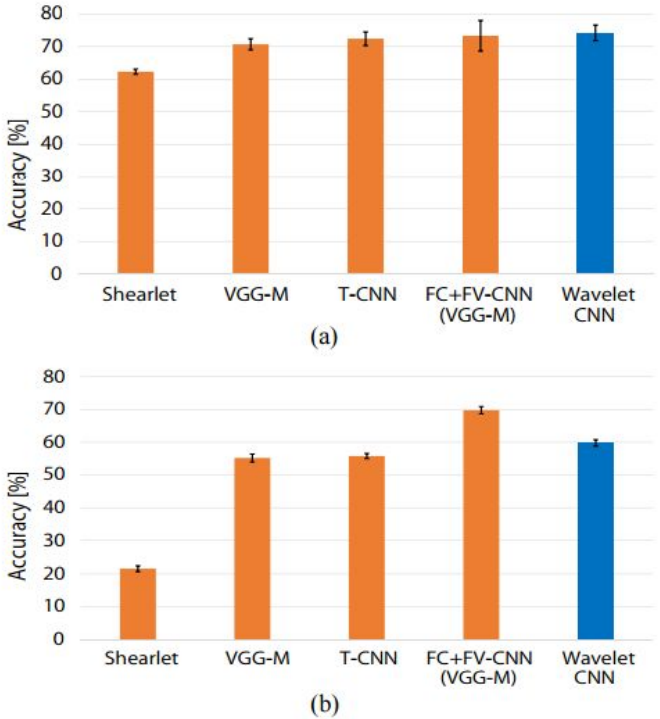
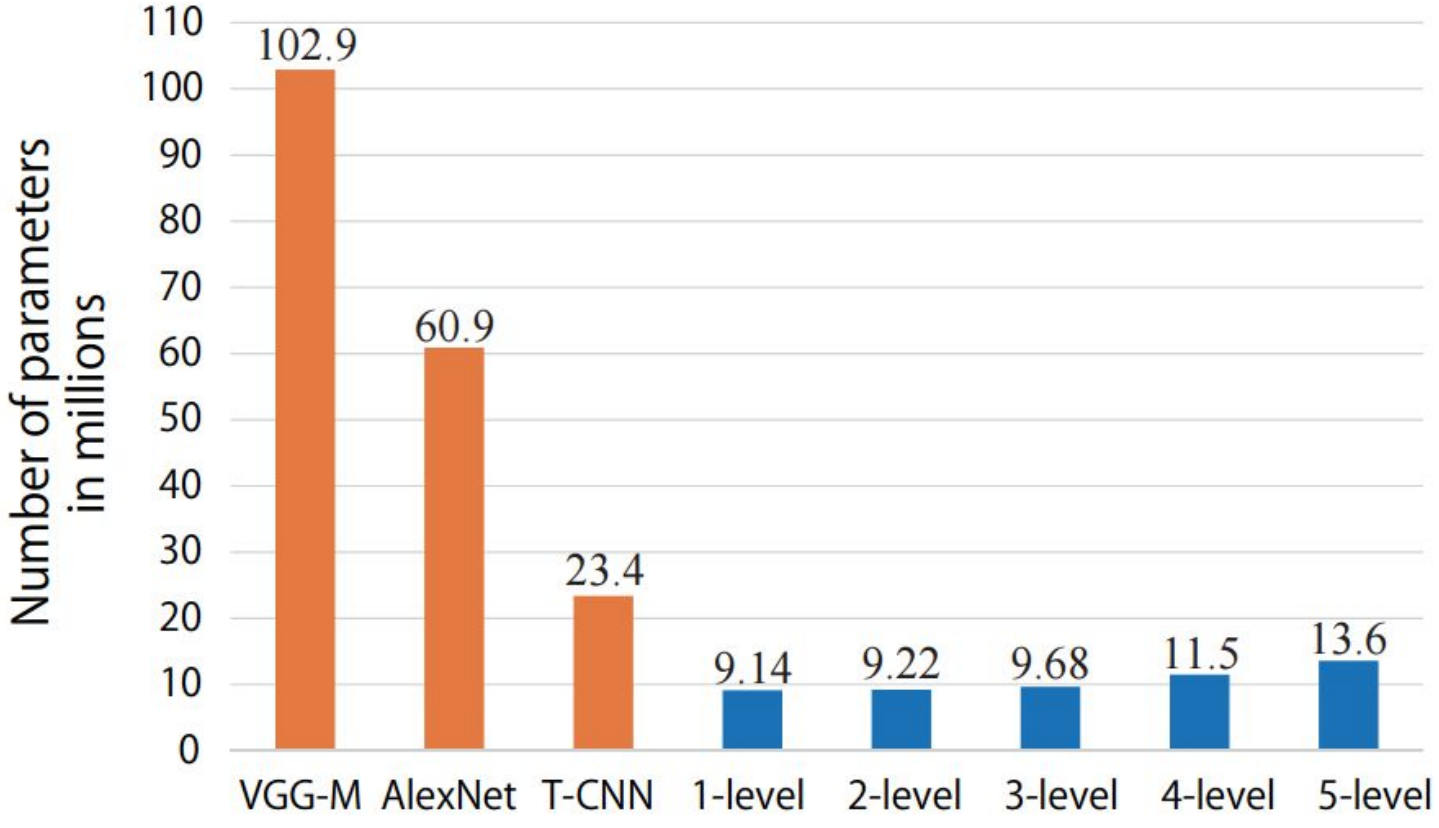
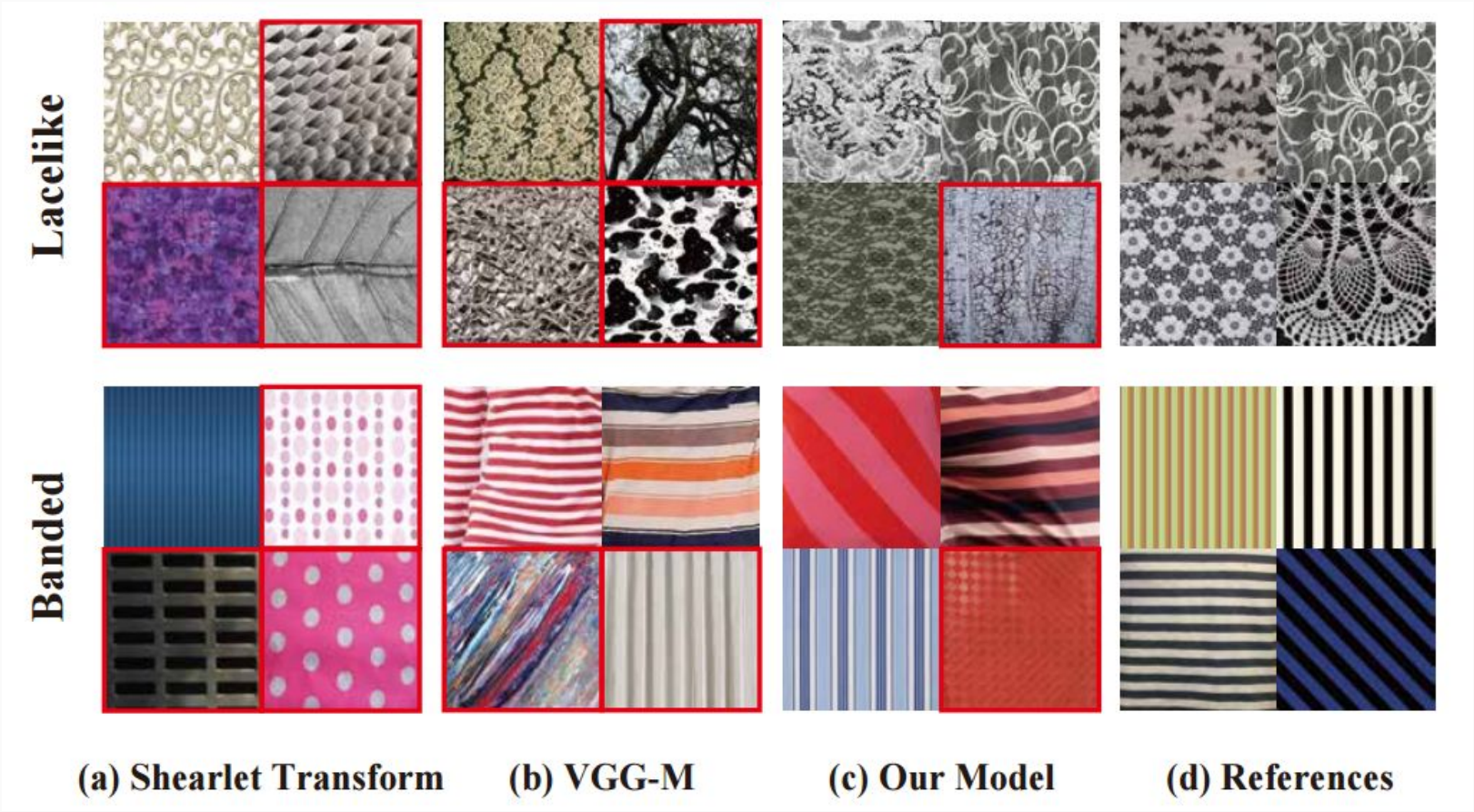


Figure 5. Classification results of (a) kth-tips2-b and (b) DTD for networks pre-trained with ImageNet 2012 dataset. We compared our model (wavelet CNN with 4-level decomposition) with shearlet transform, VGG-M, T-CNN, and FC+FV-CNN.

Results


Number of parameters in millions
110
100
90
80
70
60
50
40
30
20
10
0
102.9
60.9
23.4
9.14
9.22
9.68
11.5
13.6
VGG-M
AlexNet
T-CNN
1-level
2-level
3-level
4-level
5-level

Results


Lacelike
Banded
(a) Shearlet Transform
(b) VGG-M
(c) Our Model
(d) References

Results

Conclusion

- Совмещение спектрального подхода с CNN.
- Существенный прирост качества при меньшем числе настраиваемых параметров.
- Архитектура подходит не только для классификации текстур.
- Уровень декомпозиции ограничен глубиной сети

References

- Shin Fujieda, Kohei Takayama, Toshiya Hachisuka, **Wavelet Convolutional Neural Networks for Texture Classification.** https://arxiv.org/pdf/1707.07394.pdf
- Н. Смоленцев, Основы теории вейвлетов. Вейвлеты в Matlab