Hyperdimensional Feature Fusion For Out-of-Distribution Detection



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github.com/SamWilso/HDFF_Official

1) Method: Hyperdimensional Feature Fusion (HDFF)





2) Task: Out-of-Distribution Detection

Out-of-Distribution (**OOD**) detection challenges deep networks to alert when test-time input samples do not belong to the training distribution.



5) Cosine Similarity Test

Test-time samples are scored based on the angle of their **image descriptor** to the **nearest class bundle**:



6) Experimental Results

3) Feature Extraction and Projection

Feature maps are extracted from all Conv layers and pooled down to a vector:

 $Pool(m_l^{(i)})$

Feature vectors are projected into hyperdimensional vectors:

$$\mathbf{h}_l = \mathbf{P}_l \mathbf{v}_l \qquad \qquad \mathbf{P}^\mathsf{T} \mathbf{P} = \mathbf{I}$$

HDFF outperforms baselines and produces competitive results against Gram with ~4.5x faster inference time.

| OOD | HDFF | HDFF-Ens | Gram | MSP | ML | Energy |
|---------------|---|---|---|---|--|--|
| Dataset | (Ours) | (Ours) | [50] | [19] | [18] | [31] |
| iSun | 99.2 | 99.3 | 99.9 | 96.4 | 97.8 | 92.6 |
| TINc | 98.3 | 98.4 | 99.4 | 95.4 | 96.8 | - |
| TINr | 99.2 | 99.4 | 99.8 | 95.0 | 96.5 | - |
| LSUNc | 96.2 | 96.8 | <i>98.1</i> | 95.7 | 97.1 | 98.4 |
| LSUNr | 99.2 | 99.4 | 99.9 | 96.5 | 98.0 | 94.2 |
| SVHN | 99.4 | 99.5 | 99.4 | 96.0 | 97.2 | 91.0 |
| MNIST | 99.6 | 99.7 | 99.97 | 89.4 | 90.6 | - |
| KMNIST | 99.0 | 99.1 | 99.98 | 92.7 | 93.4 | - |
| FMNIST | 98.7 | 99.1 | 99.8 | 93.6 | 95.2 | - |
| Textures | 94.5 | 94.8 | 98.2 | 92.7 | 93.5 | 85.2 |
| CIFAR100 | 75.4 | 75.8 | 79.4 | 87.8 | 87.3 | - |
| | OOD Dataset iSun TINc TINr LSUNc LSUNr SVHN MNIST KMNIST KMNIST FMNIST FMNIST Textures CIFAR100 | OODHDFFDataset(Ours)iSun99.2TINc98.3TINr99.2LSUNc96.2LSUNr99.2SVHN99.4MNIST99.6KMNIST99.0FMNIST98.7Textures94.5CIFAR10075.4 | OODHDFFHDFF-EnsDataset(Ours)(Ours)iSun99.299.3TINc98.398.4TINr99.299.4LSUNc96.296.8LSUNr99.299.4SVHN99.499.5MNIST99.699.7KMNIST99.099.1FMNIST98.799.1Textures94.594.8CIFAR10075.475.8 | OODHDFFHDFF-EnsGramDataset(Ours)(Ours)[50]iSun99.299.399.9TINc98.398.499.4TINr99.299.499.8LSUNc96.296.898.1LSUNr99.299.499.9SVHN99.499.599.4MNIST99.699.799.97KMNIST99.099.199.98FMNIST98.799.199.8Textures94.594.898.2CIFAR10075.475.879.4 | OODHDFFHDFF-EnsGramMSPDataset(Ours)(Ours)[50][19]iSun99.299.399.996.4TINc98.398.499.495.4TINr99.299.499.895.0LSUNc96.296.898.195.7LSUNr99.299.499.996.5SVHN99.499.599.496.0MNIST99.699.799.9789.4KMNIST99.099.199.9892.7FMNIST98.799.199.893.6Textures94.594.898.292.7CIFAR10075.475.879.487.8 | OODHDFFHDFF-EnsGramMSPMLDataset(Ours)(Ours)[50][19][18]iSun99.299.399.996.497.8TINc98.398.499.495.496.8TINr99.299.499.895.096.5LSUNc96.296.898.195.797.1LSUNr99.299.499.996.598.0SVHN99.499.599.496.097.2MNIST99.699.799.9789.490.6KMNIST99.099.199.9892.793.4FMNIST98.799.199.893.695.2Textures94.594.898.292.793.5CIFAR10075.475.879.487.887.3 |

4) Feature Aggregation via Bundling

Image Descriptors are created by bundling over the multiscale features for an input sample:

 $\mathbf{y}^{(i)} = \bigoplus_{l=1}^{L} \mathbf{h}_{l}^{(i)} = \bigoplus_{l=1}^{L} \mathbf{P}_{l} \cdot \mathbf{v}_{l}^{(i)}$

Class Bundles are the bundled image descriptors for each



HDFF is compatible with OOD-based training paradigms and other post-hoc OOD detectors.

| _ | OOD | HDFF-MLP | HDFF-1DS | 1DS | NMD | DDU | MOOD |
|---|---------------|--------------|----------|-------------|-------------|-------|-------------|
| | Dataset | (Ours) | (Ours) | [59] | [10] | [37] | [30] |
| _ | iSun | 99.99 | 99.9 | _ | 99.9 | _ | 93.0 |
| | TINc | 99.9 | 99.7 | 98.1 | 99.2* | 91.1* | - |
| | TINr | 99.96 | 99.8 | 98.5 | - | 91.1* | - |
| | LSUNc | 98.2 | 99.1 | 99.4 | 98.8 | - | 99.2 |
| | LSUNr | 99.99 | 99.9 | 99.3 | - | - | 93.3 |
| | SVHN | 84.8 | 99.2 | - | 99.6 | 97.9 | 96.5 |
| | MNIST | 99.4 | 99.3 | - | - | - | 99.8 |
| | KMNIST | 98.6 | 99.3 | - | - | - | 99.9 |
| | FMNIST | 99.6 | 99.3 | _ | - | - | 99.9 |
| | Textures | 97.4 | 97.3 | - | 98.9 | - | 93.3 |
| | CIFAR100 | 69.9 | 90.7 | - | 90.1 | 91.3 | - |