Learning from Noisy Web Data with Category-level Supervision

Li Niu
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**Our Method is Based on VAE**

![Diagram of Variational Autoencoder (VAE) with outlier detection and category-level information](image)

1. outlier detection
2. category-level information

\[
p_{\theta_1}(x^i | z^i)
\]

\[
\min_{\theta_1, \theta_2} KL[q_{\theta_2}(z|x^i)||p(z)] - \log p_{\theta_1}(x^i | z^i)
\]

Regulate \(z\) to reconstruct \(x\)

Our Method to Handle Label Noise

**VAE**

\[
\min_{\theta_1, \theta_2} KL[q_{\theta_2}(z|x^i)||p(z)] - \log p_{\theta_1}(x^i|z^i)
\]

**Our Method**

\[
\min_{\theta_0, \theta_1, \theta_2} -\log p(y^i = c^i|z^i) - \log p_{\theta_1}(x^i|z^i)
\]

- **(1)**
- **(2)**

**category-level information**

**web images**

**CNN**

\[
\theta_0
\]

**encoder**

\[
\mu_z, \sigma_z
\]

**sample**

\[
z^i
\]

**decoder**

\[
\mu_x, \sigma_x
\]

**reconstruction**

\[
p_{\theta_1}(x^i|z^i)
\]

**classification network**

\[
-\log p_{\theta_2}(y^i = c^i|x^i)
\]

**bear**

**cat**

**dog**

...
Our Method to Handle Label Noise

**VAE**

\[
\min_{\theta_1, \theta_2} \text{KL}[q_{\theta_2}(z|x^i)||p(z)] - \log p_{\theta_1}(x^i|z^i)
\]

replace KL with classifier

\[
\min_{\theta_0, \theta_1, \theta_2} -\log p[y^i = c^i|z^i] - \log p_{\theta_1}(x^i|z^i)
\]

However, we only know the noisy labels \(\tilde{y}^i\) instead of the ground-truth labels \(y^i\).

**Our Method**

\[
\text{classification network} \\
\text{bear} \\
\text{cat} \\
\text{dog} \\
\ldots
\]

\[
\text{outlier} \\
\text{non-outlier}
\]

\[
\text{web images}
\]

\[\Gamma^i\] 

\[\text{CNN} \quad \theta_0\]

\[\text{encoder} \quad \mu_z, \sigma_z\]

\[\text{decoder} \quad \mu_x, \sigma_x\]

\[
p_{\theta_1}(x^i|z^i)
\]

\[
-p_{\theta_2}(y^i=c^i|x^i)
\] (1)

\[
p_{\theta_1}(x^i|z^i)
\] (2)
Our Method to Handle Label Noise

Our Method

\[
\min_{\theta_0, \theta_1, \theta_2} - \log p(y^i) = c^i | z^i) - \log p_{\theta_1}(x^i | z^i) \tag{1}
\]

replace \(y^i\) with \(\tilde{y}^i\)

\[
\min_{\theta_0, \theta_1, \theta_2} - \log p(\tilde{y}^i) = c^i | z^i - \log p_{\theta_1}(x^i | z^i) \tag{2}
\]

upper bound

\[
\min_{\theta_0, \theta_1, \theta_2} - \log \left[ p_{\theta_1}(x^i | z^i) \left( \log p(\tilde{y}^i = c^i | z^i) + \log C \right) - \log p_{\theta_1}(x^i | z^i) \right] \tag{3}
\]

weighted classification loss
Our Method to Handle Label Noise

\[
\min_{\theta_0, \theta_1, \theta_2} \left( -p_{\theta_1}(x^i | z^i) \left( \log p(y^i = c^i | z^i) + \log C \right) - \log p_{\theta_1}(x^i | z^i) \right) \tag{3}
\]
Extend our method to address the domain shift using two strategies.

**Strategy 1**: use the same VAE to reconstruct unlabeled test samples.
Extend our method to address the domain shift using two strategies.

**Strategy 2**: refine the latent variables $\mathbf{Z}^t$ of target domain samples.

**low-rank representation** [8]

[target domain $\mathbf{Z}^t$, source domain $\mathbf{Z}^s$, representation matrix (low rank), error]

[2] Liu et al., ICML 2010
Experiments

Image classification: [Google images] -> [AwA, CUB, SUN]

<table>
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<tr>
<th></th>
<th>AwA</th>
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<th>SUN</th>
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<tr>
<td><strong>Accuracy</strong></td>
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<tr>
<td>Basic CNN</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
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<tr>
<td>CNN+VAE</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Our method (without domain adaptation)</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Our method (with domain adaptation)</td>
<td>0.6</td>
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