Double adversarial domain adaptation for whole-slide-image classification

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Introduction

Image classification on whole-slide-image (WSI) is a challenging task. A previous work based on Fisher vector encoding (DFVC) [1] provided a novel end-to-end pipeline with promising accuracy and computational efficiency. However, the pipeline suffers from an accuracy drop due to domain shift. Potential causes could be different staining processes by different institutions, WSI scanned in different periods or machines, and so on. This poses a limitation on the practical use of the pipeline especially when the diagnoses of WSIs are hard to obtain. This paper is established on the DFVC pipeline and enhance it to cope with data distribution shift. We propose an Unsupervised Domain Adaptation (UDA) solution that integrates the original pipeline with domain classifiers in two stages to minimize the accuracy decrease. Comparison of a model without adaptation, adapted models, and an oracle model is demonstrated to show the effectiveness of our solution.

Method

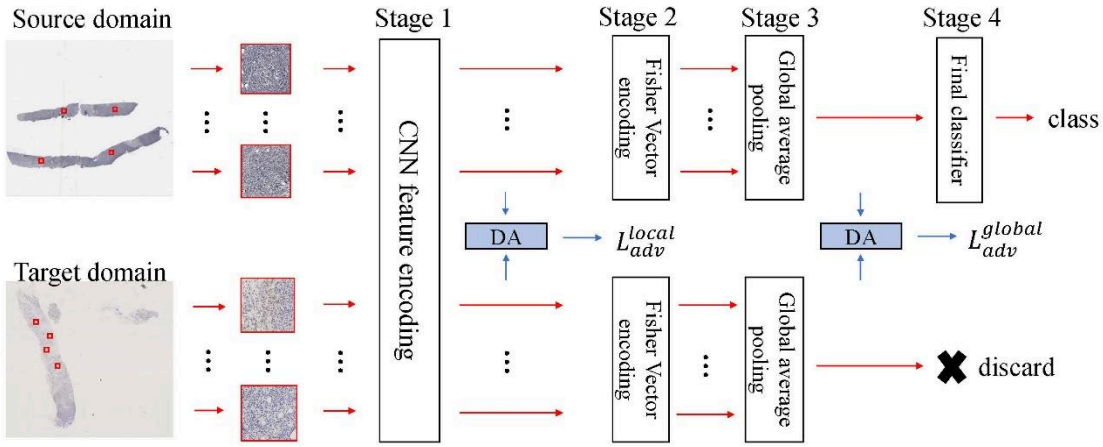
Our proposed pipeline can be separated as following steps:

- First, the WSIs of both source and target domains are randomly sampled, augmented, then fed into a CNN for feature encoding.
- Afterward, we forward the features to a domain classifier. This domain classifier works with the patch-wise features and is responsible for adapting local distribution shifts on patches from different domains. A gradient reverse layer is attached on the top of the domain classifier to enable adversarial training to adapt features from the two domains.
- Both source and target CNN encoded features from stage one are passed to the next stages (Fisher vector encoding and global average pooling).
- After the global average pooling stage which aggregates the individual features and each WSI is represented by a single vector. We insert the domain classifier to this stage to align the aggregated features. This domain classifier adapts the feature distribution shift of the entire WSI.

During the training stage, the supervised cross-entropy loss and adversarial losses are combined with a balance parameter.

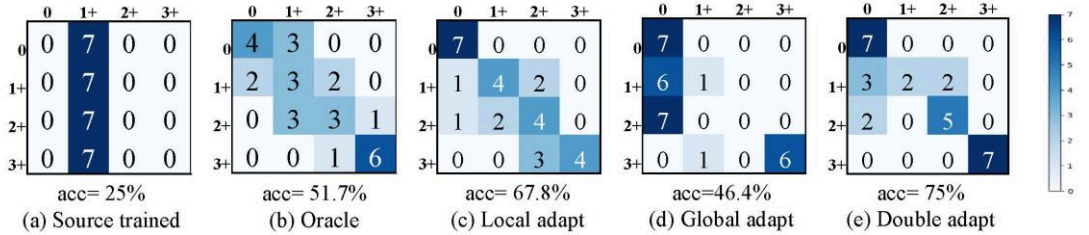
$$\begin{aligned}
&\text{Stage 1:} && \{f(x_1), ..., f(x_n)\} && \rightarrow L_{adv}^{local}\\
&\text{Stage 2:} && \{FV((f(x_1)), ..., FV(f(x_n))\} && \\
&\text{Stage 3:} && W = \frac{1}{n}\sum_{i=1}^{N} FV(f(x_i)) && \rightarrow L_{adv}^{global}\\
&\text{Stage 4:} && Y' = f_{final}(W) && \rightarrow L_{CE}\\
&\text{Final loss:} && Loss = L_{CE} + \lambda(L_{adv}^{local} + L_{adv}^{global}) &&
\end{aligned}$$

Pipeline Overview



Experiments

We test our method on two HER2 IHC breast tissue datasets (adapt from CCI to Warwick [2]). The classification goal is to predict 4 categories of HER2 scores (0,+1,+2,+3). As we can observe in the following confusion matrixes, the double stage adaptation provides the best accuracy and confusion matrix compared to the single stage adaptation in (c) and (d). Since the training set of the CCI data is significantly large compared to the Warwick dataset, the increased accuracy in this experiment also indicates that our solution can apply to the scenario where the model could be trained



Reference

[1] Amir Akbarnejad et al. Deep fisher vector coding for whole slide image classification. In Proceedings of the IEEE International Symposium on Biomedical Imaging, 2021

[2] Talha Qaiser et al. Her 2 challenge contest: a detailed assessment of automated her 2 scoring algorithms in whole slide images of breast cancer tissues.Histopathology, 72(2):227–238, 2018