DADER: Hands-Off Entity Resolution with Domain Adaptation

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ABSTRACT

Entity resolution (ER) is a core data integration problem that identifies pairs of data instances referring to the same real-world entities, and the state-of-the-art results of ER are achieved by deep learning (DL) based approaches. However, DL-based approaches typically require a large amount of labeled training data (i.e., matching and non-matching pairs), which incurs substantial manual labeling efforts. In this paper, we introduce DADER, a hands-off deep ER system through domain adaptation. DADER utilizes multiple well-labeled source ER datasets to train a DL-based ER model for a new target ER dataset that does not have any labels or with only a few labels. To address the key challenge of domain shift, DADER judiciously selects labeled entity pairs from the source and then aligns distributions of the source and the target by using six popular domain adaptation strategies. DADER can also harness the users to gather a few labels for further improvement. We have built DADER as an open-sourced Python Library with intuitive APIs and demonstrated its utility on supporting hands-off ER in real-world scenarios.

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The source code, data, and/or other artifacts have been made available at https://pypi.org/project/dader/.

1 INTRODUCTION

Entity resolution (ER) aims to determine whether two data instances refer to the same real-world entity. As a core task in data integration, ER has been extensively studied for decades [1, 3–6]. Not surprisingly, the state-of-the-art results are achieved by deep learning (DL) based approaches. A typical DL-based approach takes two data instances (or an entity pair) as input, and outputs a Boolean match/non-match result by formulating the task as a binary classification problem. However, DL-based ER approaches are typically data-hungry, i.e., requiring a large amount of labeled training data. Take Ditto [4] as an example: even leveraging pre-trained language models, Ditto still needs thousands of labels to achieve good performance. Therefore, a key bottleneck for DL-based ER is the substantial labeling efforts to create enough training data.

Fortunately, the prevalence of big data provides an opportunity of reusing a lot of labeled ER datasets (namely source datasets), either from public benchmarks or within enterprises. For example, given a new target ER task that aims to match identical products from two e-commerce websites, say Walmart and Amazon (i.e., Walmart–Amazon), it has the potential to largely reduce the prohibitive manual labeling cost, if we can reuse existing ER datasets in the same or relevant domains, e.g., the Abt-Buy dataset [5].

However, the straightforward strategy of directly reusing source ER datasets for a target ER dataset may not be effective, which may even lead to disastrous performance, due to the well-recognized domain shift problem [7]. An example of domain shift is illustrated in the upper rectangle of Figure 1 (b), where yellow circles and blue triangles respectively represent entity pairs from the source and the target. Take Abt-Buy [5] as a source and Walmart–Amazon [5] as a target. Since source and target datasets have different attributes, their vector-based features may not follow the same distribution, a DL-based model (the boundary line) trained on the source cannot correctly predict the target, e.g., all the target pairs being predicted as non-matches. To address the problem, we introduce DADER, a hands-off deep ER system (i.e., zero label for the target ER dataset) with domain adaptation (DA), which can align the features of source and target datasets and result in a good DL-based model for the target, as shown in the lower rectangle of Figure 1 (b). As reported in our experimental results [7], DA can improve the performance of Walmart–Amazon [5] by 14.2% when using Abt-Buy [5] as source.

An overview of DADER. Figure 1 illustrates how DADER achieves hands-off ER through DA that has been extensively studied in computer vision and natural language processing, yet under-explored in the ER scenarios. DADER consists of the following modules.

Source Selection. We do not presume that all entity pairs from the source ER datasets are equally useful to our target ER dataset. In fact, we may collect a large number of well-labeled source datasets in a variety of domains, such as product, citation and restaurant. Thus, DADER identifies from multiple source datasets the entity pairs that are useful to the target dataset, e.g., the 282/37/157 entity pairs from source datasets S1/S2/S3, as shown in Figure 1 (a). The key challenge here is how to measure the usefulness of each source entity pair to the target. To address this, DADER first uses a feature extractor F to map both source and target data to a high-dimensional space,
After source selection, there may be still distribution change or domain shift between the source and the target, which leads to performance degradation of the DL-based ER models. To tackle this difficulty, DADER learns from the data what is the best way of aligning distributions of source and target, such that models trained on the labeled source can be adapted to the unlabeled target. Thus, DADER adopts the most fruitful family of DA techniques, i.e., learning domain-invariant and discriminative features, and allows users to systematically explore various categories of DA solutions to find the one adequate for the current target dataset. More details can be found in our research paper [7].

Moreover, DADER helps users understand the effect of DA via visualizations, e.g., ratios of selected entity pairs in source datasets and distributions of source and target before/after feature alignment. Few-shot Labeling. DADER can also solicit users to provide a few labels to further improve the performance. Specifically, DADER samples target entity pairs with predicted labels via active learning, and asks users to verify the labels.

Differences from existing solutions. Many existing works in the literature consider reducing human labeling efforts for ER, including crowdsourcing [10] and weak supervision [9]. Compared with them, DADER focuses on reusing existing well-labeled source ER datasets, and develops a unified framework that explores the design space of DA for ER. Our experimental results [7] show that DA is very helpful to improve ER when domain shift happens. Moreover, the performance of our approach can be maintained at a high level with a few labels, while outperforming state-of-the-art DL-based ER methods, e.g., DeepMatcher [5] and Ditto [4].

Demonstration scenarios. We build DADER as an open-sourced Python Library in PyPI1. This paper demonstrates DADER’s utility in supporting hands-off ER by using the following scenarios. (1) We prepare over 20 well-labeled ER datasets in various domains and upload them to Hugging Face2. In this way, we allow different users to easily customize and access to the datasets they want to reuse. (2) For a specific target ER dataset uploaded by users, we demonstrate how the dataset benefits from DADER to quickly obtain match/non-match results, with zero label on the target dataset. (3) We show the intuitive APIs of DADER that help users easily explore the DA process, and demonstrate how DADER can further improve the ER performance given few-shot labeling from users. A demonstration video can be found on Youtube3.

To summarize, we make the following contributions. (1) We develop DADER, a hands-off deep ER system with domain adaptation. (2) DADER is helpful for users to reuse well-labeled ER datasets for a new ER task, without labels or with a few labels on the target. (3) We deploy DADER as an open-sourced Python Library and demonstrate its utility on real ER scenarios.

2 SYSTEM OVERVIEW

Given an unlabeled target ER dataset T. DADER aims to determine whether each entity pair (a, b) in T refers to the same real-world entity (i.e., match) or not (i.e., non-match). To this end, DADER employs a DL-based approach that formalizes this as a binary classification problem. To reduce expensive labeling efforts for training DL models, the goal of DADER is to reuse a set of labeled source datasets \(S_1, S_2, \ldots, S_k\) and solve the well-recognized domain shift problem by leveraging the domain adaptation (DA) techniques. Next, we will provide more details for the three modules of DADER as shown in Figure 1. Note that a typical ER pipeline consists of both blocking and matching phases, and this paper focuses on the matching phase.

2.1 Source Selection

The key challenge here is to determine which source entity pairs in source datasets \(S_1, S_2, \ldots, S_k\) are useful to the target dataset T. To solve this, DADER measures distributional similarities between source

1https://pypi.org/project/dader/
2https://huggingface.co/datasets/RUC-DataLab/ER-dataset
3https://youtu.be/vnZNOzLYV3s
and target entity pairs. We introduce a feature extractor $F$ to map each entity pair, either in source or target, into a high-dimensional vector (a.k.a. features). Following [4], we utilize pre-trained language models (e.g., BERT) to implement $F$. Given an entity pair $(a, b)$, we serialize it into a sequence of tokens $[CLS]a[SEP]b[SEP]$, where $[CLS]$ and $[SEP]$ are special tokens in BERT. Then, we feed the token sequence to BERT and obtain a feature vector. After that, we develop two methods for selecting similar source entity pairs. (1) A classifier-based method trains a domain classifier on all the data, and selects the source entity pairs that are not easily distinguishable from the target. The classifier can be implemented by a machine learning model, such as multi-layer perceptron (MLP) or Random Forest. (2) A metric-based method uses simple distance metrics, such as cosine similarity or euclidean distance, to select source entity pairs. Furthermore, as it may be time-consuming to perform the aforementioned process for all source entity pairs, we devise an efficient TF-IDF based strategy to first filter out the source entity pairs which are not textually similar enough to the target.

2.2 Feature Alignment

The key challenge is how to align distributions of the source and target datasets, such that models trained on the source can predict well for the target. DADER adopts the most popular and fruitful family of DA techniques on learning domain-invariant and discriminative features for both source and target datasets. Along this line, DADER develops six popular DA strategies falling into three categories, which will be briefly described below. Please find more details about these strategies in our research paper [7].

- **Discrepancy-based** approaches use statistical metrics to minimize the domain distribution discrepancy between source and target datasets. DADER provides two metrics: Maximum Mean Discrepancy (MMD) and $K$-orders, which have been shown very effective. Specifically, during training, these methods compute statistical distribution discrepancy on top of the features of source and target datasets, and reduce the discrepancy via back propagation, so as to make distributions of source and target as close as possible.

- **Adversarial-based** approaches use adversarial training to adjust feature extractor $F$ to map source and target data into an appropriate feature space. To this end, the approaches implement the feature aligner as a domain classifier, which is trained to distinguish features from source or target, while the feature extractor $F$ tries to generate the features that can confuse this domain classifier. In this way, we can align distributions between source and target to reduce domain shift. DADER realizes three representative adversarial-based methods, namely gradient reversal layer (GRL), inverted labels GAN (InvGAN) and InvGAN + Knowledge distillation (KD).

- **Reconstruction-based** approaches introduce an auxiliary unsupervised reconstruction task. Specifically, the feature aligner is used as the decoder to reconstruct the input of feature extractor $F$, to ensure that features contain useful and shared information across the source and target datasets. DADER provides the Encoder-Decoder (ED) networks to support this strategy on ER.

2.3 Few-shot Labeling

The previous Source Selection and Feature Alignment are totally **hands-off**, i.e., the system can automatically complete the entity matching task without human intervention. DADER can adopt few-shot learning to further improve the performance of ER results on the target with human interaction. To this end, DADER uses active learning strategies to sample a small subset of target entity pairs, and asks the users to verify their labels. After gathering users’ feedbacks, DADER can utilize the limited number of target labels to refine our models, which would result in further improvement on the ER results. This few-shot labeling process can repeat multiple rounds until the user is satisfied with the results.

3 DEMONSTRATION SCENARIOS

In this section, we will walk through a concrete example to demonstrate how to use DADER for hands-off ER.

**Unlabeled target ER dataset.** We will use iTunes-Amazon, a dataset about music from Magellan [2]. It contains two tables from websites iTunes and Amazon, respectively. Each entity in the tables consists of ten attributes (e.g., Song-Name, Artist-Name, Price). Note that we presume that this ER dataset does not have any label.

**Labeled source ER datasets.** We prepare over 20 well-labeled ER datasets in various domains and upload them in Hugging Face, as described in Section 1. These datasets cover ten domains, including product, movie, book, citation, restaurant, and so on.

**Goals.** We have three demonstration goals. (G1) DADER can automatically select labeled source entity pairs from multiple datasets that are possibly from different domains, a.k.a. Source Selection. (G2) DADER can align the features of source and target entity pairs, a.k.a. Feature Alignment. DADER will then train a binary classifier using selected labeled source entity pairs, which will be directly applied to unlabeled target entity pairs, a.k.a. Hands-off ER. (G3) DADER also offers intuitive interfaces that allow the audience to give a small number of labels for the target dataset to further improve the model performance, a.k.a. Few-shot labeling.

Next we describe the following concrete steps corresponding to the above three goals, as shown in Figure 2.

1. **Step 1: Source Selection.** We first use the “Upload” button to upload our target dataset iTunes-Amazon. Then, we fetch our well-labeled source ER datasets from the aforementioned repository in Hugging Face. Next, we call the “SelectSource” function with parameters, such as the maximum number of selected source tuple pairs. This function will automatically select source entity pairs that are useful to the target. In order to help users understand how source tuples are selected, we use histograms to visualize the numbers of selected data pairs from different source datasets. As illustrated in Figure 2, we can see that DADER selects a large number of data pairs from Amazon, Google, Walmart, and Abt-Buy, which are highly similar with our target dataset iTunes-Amazon. Interestingly, the pie chart in the figure shows that most of the selected data instances are from e-commerce website Amazon. The main reason is that our target dataset iTunes-Amazon also contains many music records from Amazon, and the selected data pairs are similar to the target, e.g., having similar vocabularies. Furthermore, if users are not satisfied with the result, they can customize their own source selectors via our intuitive APIs to achieve desired results.

2. **Step 2: Feature Alignment.** We directly call the encapsulated package to train the models with four lines of code. Here, as an example, we use the default BERT model and InvGAN+KD strategy (see
Figure 2: Demonstration scenarios of DADER on dataset iTunes–Amazon in the Music domain.

Section 2). Users can adjust parameters as required. To show the changes of feature distributions before and after feature alignment, we use t-SNE [8] to map the features of source and target datasets into a two-dimensional space and plot all entity pairs in the space. From the two plots, we can clearly see that source and target entity pairs are obviously more mixed when we apply DA, which indicates the domain shift reduction. To show the performance of the models, we draw the F1-score curve of target validation set during training. Based on this, the user can know the training process of the model. The training process takes around three minutes to converge. Finally, The F1-score achieved by DADER on the iTunes–Amazon dataset is 0.86, with zero label from the target dataset.

Step 3: Few-shot Labeling. We sample some predicted results of target to users via active learning, as described in Section 2.3. Each entity pair with a green tick indicates that the corresponding predicted label is matching, while the rest ones are non-matching. Users can view the data and update labels by clicking the corresponding rows. Then these sampled data with predicted labels or manually annotated true labels will be used to retrain the models. This step can repeat multiple rounds until the user is satisfied with the results. Here for our iTunes–Amazon example, we sample a set of 50 predicted results in one round and update labels of only three entity pairs in the sample, which then improves the F1-score of the predicted ER results from 0.86 to 0.90.

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