Using Non-Task Data To Solve Cold Start Problems in Heterogeneous Peer Prediction

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Abstract

- This document describes the expected style, structure, and rough proportions for your final project write-up.

- While you are free to break from this structure, consider it a strong prior for our expectations of the final report.

- Length is a hard constraint. You are only allowed max **8 pages** in this format. While you can include supplementary material, it will not be factored into the grading process. It is your responsibility to convey the main contributions of the work in the length given.

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1. Introduction

In peer prediction settings with heterogeneous users, the goal is to make truthful reporting a low-regret strategy for any agent. To fully minimize expected regret while allowing for heterogeneity, this would require the computation and use of individualized user-user signal correlations for every pair of users. This is in general computationally infeasible, so methodologies typically focus instead on clustering similar users while trying to minimally distort their individual signal distributions.

Additionally, because this method explicitly requires an existing signal distribution, there is a cold start problem: if we do not already have a significant amount of task data for a new user, we cannot know how properly to reward them in comparison to their peers. In our project, we focus on two specific goals:

1. Clustering is usually done by comparing each user's reports with other users. We aim to speed up this clustering by using latent variable matrix factorization and then clustering on much smaller latent variables.

2. Bootstrapping the clustering process by using non-task data to form an initial clustering before agent reporting begins.

2. Background

In Shnayder et al. (2016), Shnayder et al. prove that the Correlated Agreement multi-task peer prediction mechanism maximally incentivizes truthful reporting without a ground truth for homogeneous users. The CA mechanism can be generalized to non-homogeneous users but requires a prohibitive number of user reports; thus, Agarwal et al. (2017) bounds expected regret by clustering users with similar signal-report distributions. This regret bound is proportional to the L1 difference between user-user 'Δ Matrices' and those of their respective clusters, where a Δ Matrix of users q, r is defined as:

$$D_{q,r}(i,j) = p(\text{q reports i, r reports j}) - p(\text{q reports i})p(\text{r reports j})$$

The primary dataset we use is that of the Good Judgment Global Forecasting Competition, available at `https://dataverse.harvard.edu/dataverse.xhtml?alias=gjp`. There are many challenges inherent to this dataset. First, the idea of a task is not well-defined. Users enter predictions in continuous time, and the true probability of an event will change over time, such that each minute could be considered a different task (Note that if we expect users only update their predictions

in response to new information, these time-question tasks will be independent conditional on the signal). We choose to bucket these responses by week to mediate between the desire to allow for variation in true probability over time while maintaining sufficient task response density. This results in 1,499,294 predictions by 2,052 users on 1,548 tasks. Secondly, the signal itself can be expected to have a high degree of noise, as the probability of any of these global events is not well-defined even in the absence of individual interpretation effects.

To study the effects of the clustering methodologies in a slightly less noisy realm, we additionally use a second dataset of user judgments on whether or not websites contained adult content. This dataset, termed *Adult*, was pulled from the Square Project at the University of Texas. The data is available at `https://github.com/ipeirotis/Get-Another-Label/tree/master/data`. We limit the dataset to users who gave at least one report of each signal, resulting in 65,144 reports by 389 users on 10,381 tasks.

Both datasets required significant preprocessing to account for sparsity of signal distributions and to compute the Δ matrices. Additionally, because Good Judgment reports were continuous rather than discrete, we bucketed the responses into five uniform bins, which we use to compute the matrices.

3. Related Work

(Agarwal et al., 2017) is the only paper we know of specifically considering clustering methods for heterogeneous peer prediction. The paper differs from our work in that it assumes all of the relevant data exists and seeks to prove a theoretical upper bound on regret rather than to study empirical average regret in settings with sparse data. While the authors also use the *Adult* dataset among others, they restrict it to a small subset of only those users for whom there is a full joint distribution between any two users, resulting in only 269 users.

Further, while the authors prove a theoretical bound in the case of empirically estimated ground truth, the tests they run on real data rely on the existence of a known ground truth label. This allows them to calculate individual signal confusion matrices using methods developed in Dawid & Skene (1979) and leverage tensor decomposition techniques from Anandkumar et al. (2014) and Zhang et al. (2016) to compute average clusters directly. We seek to show that in the more general case of incomplete data with no ground truth labels, clustering instead on user-specific latent variables learned through matrix factorization can lead to similar computational savings as tensor decompo-

sition while eliminating the need for labels. Further, we show that these computationally efficient clusterings are similarly effective with respect to incentivizing truthfulness as clustering on Δ matrices directly.

The use of the Correlated Agreement mechanism (Shnayder et al., 2016) requires that the Δ matrices are already known or can be empirically estimated from observed data. Nothing in the peer prediction literature addresses this cold start problem yet. However, it is well studied in the field of matrix factorization. The most similar method to ours, in that it incorporates non-task data, is (Kula, 2015).

4. Model

Given a sparse matrix containing tasks, users, and users' reports on each task, the goal is to produce clusters which accurately describe users' reporting behavior. Because of the sparse matrix data, we focus on matrix factorization models to generate latent factor representations of users. That is, we assume that there is some latent variable representation of a user's forecasting behavior, u_i that interacts with related task-specific factors, t_j. These could be thought of, for example as the task's topic areas and the user's expertise in those specific topic areas. After transforming the predictions to range from -1 to 1 instead of 0 to 1, we use the following model, shown in Figure 1:

$$p_{i,j} \sim \mathcal{N}(\tanh\left(\mu_{i_M}\left[u_i^T t_j + g + \mu_j\right] + \mu_{i_A}\right), \sigma^2)$$

Users tend to exhibit two forms of individualized biases in this space. The multiplicative bias, μ_{i_A} captures either risk aversion or overconfidence, such that they tend to predict values either closer to or farther from 0 (.5) than are warranted by their knowledge. The additive bias, μ_{i_M} captures both availability bias or normalcy bias which would result in user having a tendency to predict a specific level. The task bias μ_j captures the general prediction likelihood of the task absent user-specific factors, and the global bias g captures the overall mean of the user-task predictions. The tanh restricts the space of the predicted mean to the domain of the target value.

Then, we must infer $k + 2$ parameters for each user, $k + 1$ parameters for each task, and one global bias, where k is the length of the latent vector representation we choose for users and tasks. Only the predictions $p_{i,j}$ are known in this model.

For *Adult*, which does not have this probablistic representation and has reports ranging from 1 to 4, we use only additive biases and remove the tanh.
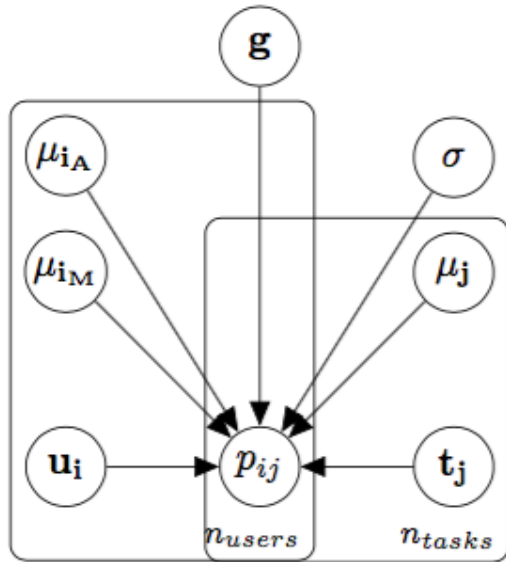
XX TODO PREDICTING LATENT USER VECTORS FROM PSYCH DATA XX

Figure 1. Model of prediction generation.

5. Inference (or Training)

- How do you plan on training your parameters / inferring the states of your latent variables (MLE / MAP / Backprop / VI / EM / BP / ...)

- What are the assumptions implicit in this technique? Is it an approximation or exact? If it is an approximation what bound does it optimize?

- What is the explicit method / algorithm that you derive for learning these parameters?

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6. Methods

- What are the exact details of the dataset that you used? (Number of data points / standard or non-standard / synthetic or real / exact form of the data)

- What are the exact details of the features you computed?

- How did you train or run inference? (Optimization method / hyperparameter settings / amount of time ran / what did you implement versus borrow / how were baselines computed).

- What are the exact details of the metric used?

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Algorithm 1 Your Pseudocode

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7. Results

- What were the results comparing previous work / baseline systems / your systems on the main task?

- What were the secondary results comparing the variants of your system?

- This section should be fact based and relatively dry. What happened, what was significant?

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Table 1. This is usually a table. Tables with numbers are generally easier to read than graphs, so prefer when possible.
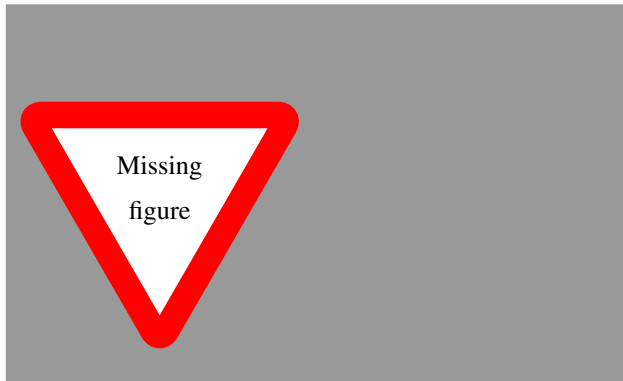

Table 2. Secondary table or figure in results section.

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8. Discussion

- What conclusions can you draw from the results section?

- Is there further analysis you can do into the results of the system? Here is a good place to include visualizations, graphs, qualitative analysis of your results.

- What questions remain open? What did you think might work, but did not?

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9. Conclusion

- What happened?

- What next?

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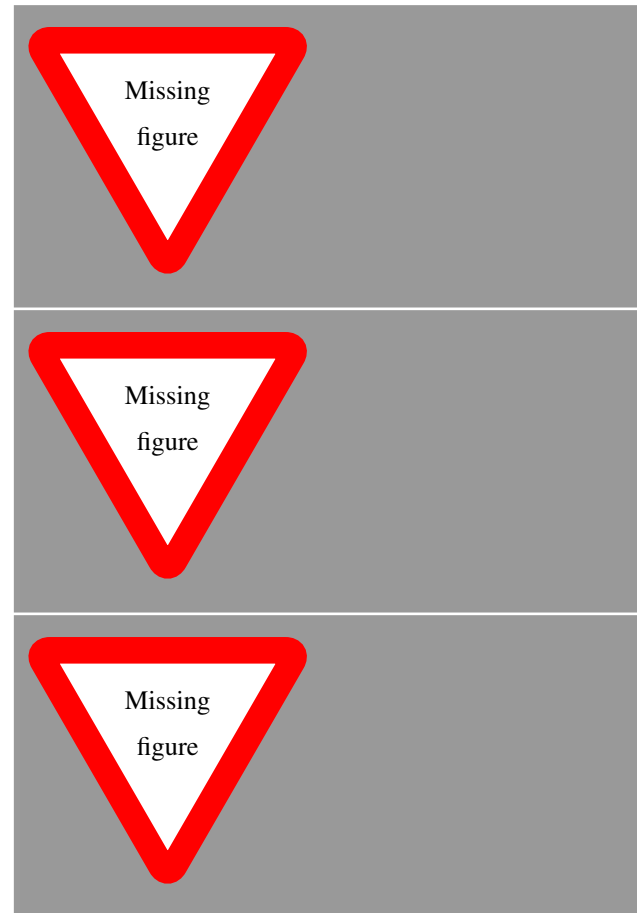

Figure 2. Visualizations of the internals of the system.

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