
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 in-

feasible, 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:

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

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

Example Structure:

- What 3-5 papers have been published in this space?
- How do these differ from your approach?
- What data or methodologies do each of these works use?
- How do you plan to compare to these methods?

(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 decomposition 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

Example Structure:

- What is the formal definition of your problem?
- What is the precise mathematical model you are using to represent it? In almost all cases this will use the probabilistic language from class, e.g.

$$z \sim \mathcal{N}(0, \sigma^2) \quad (1)$$

But it may also be a neural network, or a non-probabilistic loss,

$$h_t \leftarrow \text{RNN}(x_t, h_{t-1})$$

This is also a good place to reference a diagram such as Figure 1.

- What are the parameters or latent variables of this model that you plan on estimating or inferring? Be explicit. How many are there? Which are you assuming are given? How do these relate to the original problem description?

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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?



Figure 1. This is a good place to include a diagram showing how your model works. Examples include a graphical model or a neural network block diagram.

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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Algorithm 1 Your Pseudocode

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

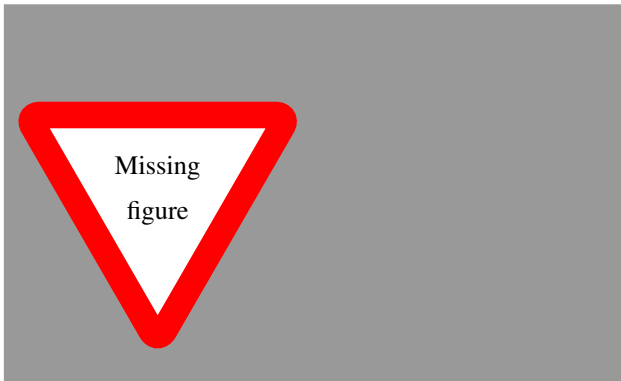


Table 2. Secondary table or figure in results section.

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9. Conclusion

- What happened?
- What next?

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Figure 2. Visualizations of the internals of the system.

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