

# CS378: Final Project - Data Artifacts

[https://github.com/sarimaleem/cs378\\_fp](https://github.com/sarimaleem/cs378_fp)

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## Abstract

This paper describes the training and testing of an ELECTRA model for natural language inference using the Stanford Natural Language Inference Dataset. The model's performance is benchmarked using contrast sets, and data cartography is used to improve the model's accuracy. The results show that the base ELECTRA model performs well on the dataset, and extracting ambiguous examples from data cartography and training the model on them is an effective method for improving its performance for some aspects.

## 1 Introduction (5pt)

Natural language inference is the task of determining the truth value of a hypothesis given a premise. A hypothesis can either be true if it entails from the premise, false if it contradicts the premise, or neutral if a determination cannot be made either way. In this paper, train a model based on the Stanford Natural Language Inference Dataset (SNLI).

We find that the SNLI model has difficulty differentiating between neutral labels, and labels of other classes. We also find that the model often is unable to contextualize and relate the semantics of different words that have the same meaning. We created a contrast set in order to test the model, and found that the performance of the model is significantly degraded in comparison to the validation set.

In order to reduce ambiguity between words, we decided to train the model on ambiguous data - data with high variability and medium confidence. We found that training that although training the model on ambiguous data reduced the models overall performance, the performance of the model increased on adversarial data, which we dubbed contrast sets.

## 2 Task/Dataset/Model Description (15pt)

The model that was used was the ELECTRA model [2]. We are training on the stanford NLI dataset [1]. The dataset has 570000 training examples and 10000 validation examples. The baseline ELECTRA modeled was fine tuned to the SNLI training set and was trained with three epochs. We used the default loss function from the hugging face transformers library.

For the fix, we took ambiguous data from the first 50000 training examples and trained on those for 15 epochs.

**TODO:** Describe the task/dataset/model you are working on. Clearly define your task with mathematical notations. Describe your learning algorithm. You must formally specify the loss function, stopping criteria, training data, etc used for the model you are analyzing in the next section. Remember, every notation you use must be defined.

## 3 Performance Analysis (25pt)

The model was trained for 3 iterations on the SNLI training dataset. Each iteration has 550152 training examples, the batch size for the training examples was 32. All training was done on google colab in the cloud, and training took about 25 minutes.

### Overall Accuracy Statistics

An initial evaluation of the model shows that it has an accuracy of 88%. We also did further evaluation to show statistics about which labels it misclassified most using a confusion matrix.

Table 1: Development Set Evaluation Metrics

loss	0.315
accuracy	0.8865
runtime	20.2629
examples/s	485.715
steps/s	60.751

*Model Metrics for 9842 examples*

Table 2: Confusion Matrix

	Predicted				Total
		0	1	2	
	0	2996	252	81	
	1	213	2787	235	
	2	79	257	2942	
	Total	3288	3296	3258	<b>9842</b>

*0=Entailment, 1=Neutral, 2=Contradiction*

Table 3: Percent mispredictions

	Predicted			
		0	1	2
	0	89.99	7.78	2.47
	1	6.39	86.15	7.16
	2	2.37	7.94	89.74

*0=Entailment, 1=Neutral, 2=Contradiction*

### 3.1 Confusion Matrix Analysis

In general, the model seems to do well with Separating Entailment and Contradiction. For example, it only incorrectly identifies 2.47% of entailment examples as contradiction and 2.37% of contradiction examples as entailment.

However, the model struggles more to understand the relationship between, entailment and neutral, as well as contradiction and neutral. For example, it mispredicted over 7% of entailments and contradictions as neutrals. As long as mispredicting over 6% of neutrals as entailments and over 7% of neutrals as contradictions.

### 3.2 Manual Pattern Analysis

It’s difficult to say how the model is evaluating sentences, since it’s impossible to fully understand its weights. Nevertheless, there do seem to be some patterns one evaluating mistakes that the model makes. One pattern that seems to happen is that the model seems to be unable to understand different words that mean the same thing in a context. For example, the following is an error that the model made.

In the example with hypothesis *A man and a woman are looking at produce on display* and premise *A man and woman are staring at heads of lettuce*. The model is unable to distinguish that lettuce is a type of produce and instead makes assumption that they are different, thus leading it to think they are contradictions.

### 3.3 Using Contrast sets to evaluate the Model

subsectionContrast Sets

In their article *Evaluating models’ local decision boundaries via contrast sets* [3], Gardner et al. explain the concept of a *contrast set*. A contrast set is a small but meaningful alteration in the input data that typically leads to a different gold label.

In order to test if the model is finding artifacts in the data or genuinely evaluating it, we annotated 35 different examples in the validation data that the model predicted correctly, and then tested to see if the model was able to predict them correctly again.

The results of the model showed a significant dip in accuracy, with accuracy going down to 77% from 89%. The model mispredicted 8/35 examples. One pattern that emerged from the mispredictions is that the model fails to see correlations between various words and also fails

Table 4: Examples of model misunderstanding words, or not considering their importance

premise	Hypothesis	Gold	Predicted
People are throwing tomatoes at each other	The people are having a food fight	entailment	contradiction
A man and a woman are looking at produce on display.	A man and women are staring at heads of lettuce.	neutral	contradiction
Two men sitting on a subway are reading, with coats and scarves on, but have seemed to have lost their pants.	The men are wearing pants.	contradiction	entailment
Two men are in an electronics workshop, working on computers or equipment	The men are unaware of what computers are.	contradiction	neutral

to understand the relationships between various words. The following is an example of this phenomenon:

premise: Two men on vehicles competing in a race.  
hypothesis: Men are riding cars on the street.  
label: neutral  
predicted: contradiction

The neural network is essentially unable to distinguish that different words can have the same meaning (in this case vehicles and cars).

## 4 Describing Your Fix (20pt)

It is clear that the issue with the model is that it fails to understand ambiguous training examples. This is especially seen given that the model largely confuses, as seen earlier, neutral and entailment and instances of contradiction.

### 4.1 Dataset Cartography

Training on labels that are ambiguous, that have high variability, should in theory help with this issue, even more so than hard to learn labels. An ambiguous label is defined as a label that has high variance when predicted by different iterations of the model. For example, a model that is trained on 500 iterations would predict the input differently than a model trained with 1000 iterations or a model trained with 1500 iterations. Furthermore, the average confidence of that training example is not high or low. [4] We reproduced the

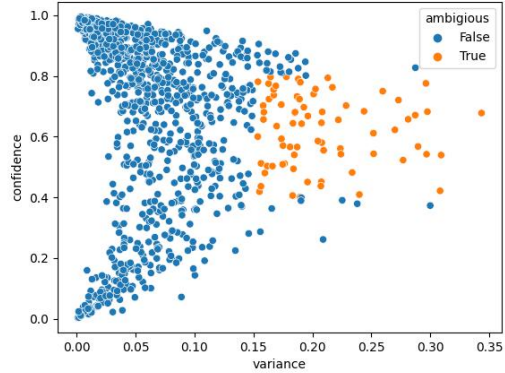


Figure 1: Data Cartogram of 2000 training examples, orange ambiguous

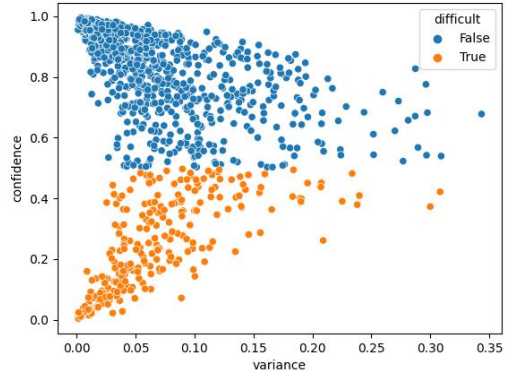


Figure 2: Data Cartogram of 2000 training examples, orange difficult

code to analyze data, and have plotted 500 training examples in figure 1.

In order to deal with this, we first created a program that finds ambiguous examples. We found the variance of the training example based on its confidence of the gold label from a modeled trained on 500 iterations, 1000 iterations, 1500 iterations, 2000 iterations, 2500 iterations, and 3000 iterations. If the variance was greater than 0.15, and the confidence of the model was in between 0.4 and 0.8, the example was deemed ambiguous. According to *Swayamdipta et al.*, training solely ambiguous examples leads to greater performance than training on the whole dataset, only easy to learn examples, or only hard to learn examples. Thus it is logical to train on these examples.

We pulled 1655 ambiguous samples from the training data and trained on those examples. We trained for 15 epochs on ambiguous examples. As a test, we also trained solely on difficult to learn examples for five epochs, of which there were 6915, and benchmarked their performance.

## 5 Evaluating Your Fix (25pt)

We evaluated the new model that was trained on hard to learn examples and independently trained on ambiguous examples. We found that models trained on ambiguous examples tended to do better with more difficult data, but tended to reduce the models overall average. For example, the accuracy of the model trained on ambiguous data and tested on the contrast set was 80%, whereas the model that was not trained on ambiguous data had an accuracy of 77%.

Based on manual evaluation of the contrast set, there is some evidence that the model is able to reason better about differentiating between entailment and contradictions (given that they have no errors) and in some instances better predicts neutrals. The following is a good example of this phenomenon:

premise: Under a blue sky with white clouds, a child reaches up to touch the propeller of a plane standing parked on a field of grass.  
hypothesis: A child is not reaching to touch the propeller out of curiosity.  
label: neutral  
predicted: neutral

Unlike the the baseline model, which does not see the relationship that *not* has in the sentence

Table 5: Ambiguous Trained Model on Contrast Set

		Predicted		
		0	1	2
True	0	90	7.692307692	0
	1	10	61.53846154	30.76923077
	2	0	7.692307692	92.30769231

0=Entailment, 1=Neutral, 2=Contradiction

Table 6: Ambiguous Trained Model on Validation Set

		Predicted		
		0	1	2
True	0	83.53	9.79	7.04
	1	6.39	79.75	13.48
	2	2.70	7.48	89.871

0=Entailment, 1=Neutral, 2=Contradiction

(negating curiosity, not touching), the model that is trained on ambiguous data is able to distinguish examples like these.

However, the model that was trained on ambiguous data seemed to suffer on the overall benchmark of the evaluation set. The accuracy dropped from 88% to 84% on the validation set.

The most surprising results were the difficult to learn examples. The accuracy of that model was significantly lower than base model, clocking in an accuracy of 13%. Even a model with random guessing could have done better.

Due to time constraints, more ambiguous labels could not be extracted, but it’s certainly possible that if all 500000 training examples are indexed and ambiguous ones are found, that the model could have better performance than it currently does. Furthermore, it is clear that training only on difficult to learn examples degrades model performance significantly.

## 6 Related Work (5pt)

Zhang et al. [5] propose another algorithm that uses data cartography called “cartography active learning”. However, their approach differs slightly in that they actively select ambiguous and difficult examples *during* training and then adjust the input of the training in real time to train on the ambiguous data. In contrast, our approach finds ambiguous and difficult data after an initial

training period and then trains on that data.

## 7 Conclusion (5pt)

In this paper, we evaluate an ELECTRA based ML model on the Stanford Natural Language Inference dataset. We find that the model has difficulty differentiating between neutral labels and other classes and that it finds at times spurious correlations between the premise and hypothesis. We also find that the model suffers significant performance degradation when tested against a contrast set. To remedy this, we recommend finding ambiguous labels (labels with high variability and medium confidence) using data cartography, and train the model on those data points in addition to the training set. Although not a perfect method, training on ambiguous labels can help the model learn more difficult correlations.

## References

- [1] Samuel R Bowman, Gabor Angeli, Christopher Potts, and Christopher D Manning. A large annotated corpus for learning natural language inference. *arXiv preprint arXiv:1508.05326*, 2015.
- [2] Kevin Clark, Minh-Thang Luong, Quoc V. Le, and Christopher D. Manning. Electra: Pre-training text encoders as discriminators rather than generators, 2020.
- [3] Matt Gardner, Yoav Artzi, Victoria Basmova, Jonathan Berant, Ben Bogin, Sihao Chen, Pradeep Dasigi, Dheeru Dua, Yanai Elazar, Ananth Gottumukkala, et al. Evaluating models’ local decision boundaries via contrast sets. *arXiv preprint arXiv:2004.02709*, 2020.
- [4] Swabha Swayamdipta, Roy Schwartz, Nicholas Lourie, Yizhong Wang, Hananeh Hajishirzi, Noah A. Smith, and Yejin Choi. Dataset cartography: Mapping and diagnosing datasets with training dynamics, 2020.
- [5] Mike Zhang and Barbara Plank. Cartography active learning, 2022.