Homework 4

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CSE 546 Machine Learning

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1 Hubris

When I started my experiment, I accidentally bit off far more than I could chew in terms of compute time. It was going to take me an estimated 33 hours of compute time simply to do a basic grid search of the SVM with the 4 preprocessing choices, 3 kernel choices, and minimal hyperparameter searching (less than 7 options for each option). This is not even considering any runtime for MLPNet.

So, I redirected my efforts to do some simpler experiments on a smaller set of data in order to identify any ways that I can simplify my search on the full dataset.

2 Initial Search

I began my experiment using only 800 training samples of the original dataset, but with a wide variety of gridsearch choices. The purpose of this wide gridsearch was to identify a smaller band of options for continuous parameters such as gamma or C, see if we can clearly identify a standout option of the degree for the polynomial kernel, and (most importantly) identify the best preprocessing method for the data. We can see the result in Figure 1.

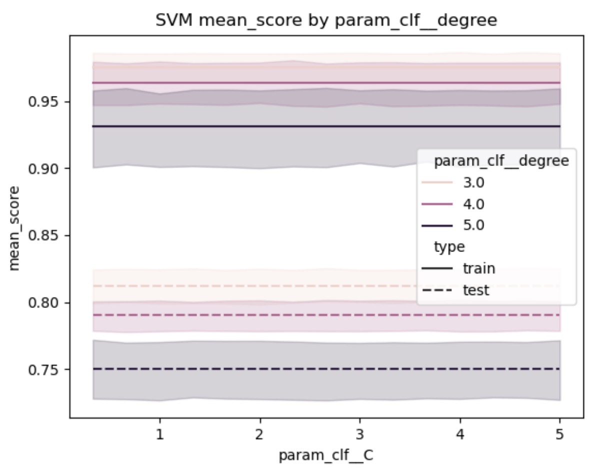
As we can see from these plots, the polynomial degree of 3 is best across the board (this was true at every step for every other parameter as well, the C parameter just looked the clearest). Likewise the standard scaler performed the best for SVM and MLPNet (while also training faster!). Unfortunately I didn't feel like there was a clear cut best kernel because of the huge disparity in overfitting behavior between the different kernels.

From all of this, I decided to do the following: I cut out all preprocessors other than the Standard-Scaler, all polynomial degrees other than degree of 3, and I restricted my search for gamma and C to be between .2 and 2 in steps of .2. Even with these simplifications, when I moved on to work with the full dataset it took over 8 hours.

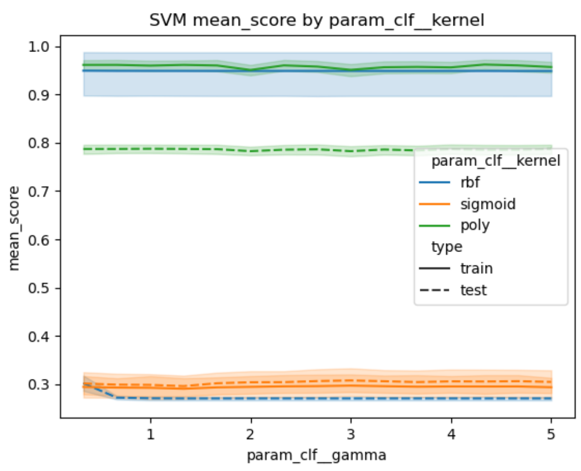
3 Final Search

I did my final search over the parameters explained above for the SVM, and I did 3 different MLPNet models with alpha from the list [0, .0001,.001,.01,.1] and a learning rate from the list [.0001, .001,.01,.1]. The 3 different MLPNet models are described by a list of their hidden layer sizes, and all used the same activation function.

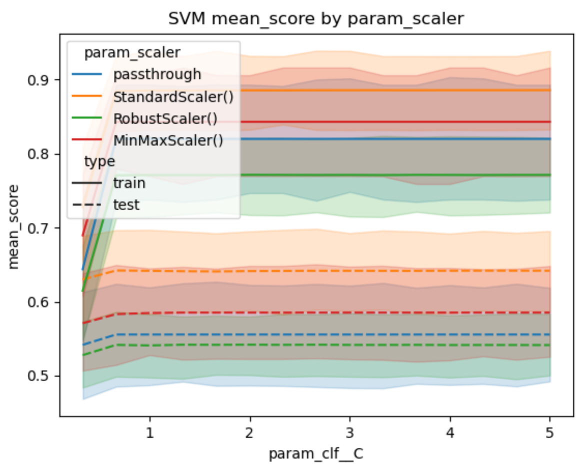
We can see the results of the gridsearch in Figure 2, and the best models in Table 1. Since the parameters are cut off for size, I will provide the results here. Best SVM had a C of .2, gamma of 1.0, and the polynomial kernel. The best MLPNet model had an alpha of .0001, layout of [128,64,64,32], and a learning rate of .001.



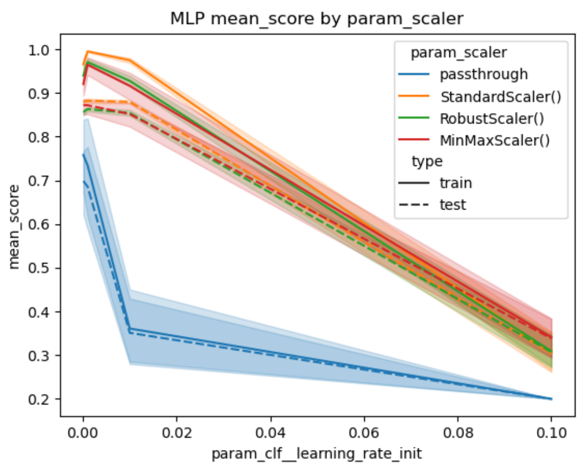
(a) Polynomial SVM Degree Performance



(b) Kernel Performance



(c) Preprocessing Performance for SVM

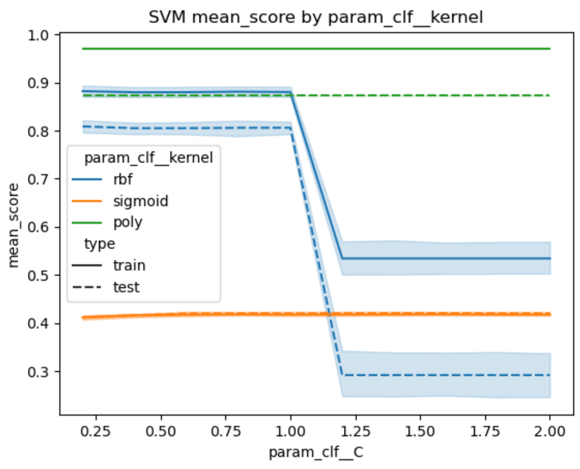


(d) Preprocessing Performance for MLPNet

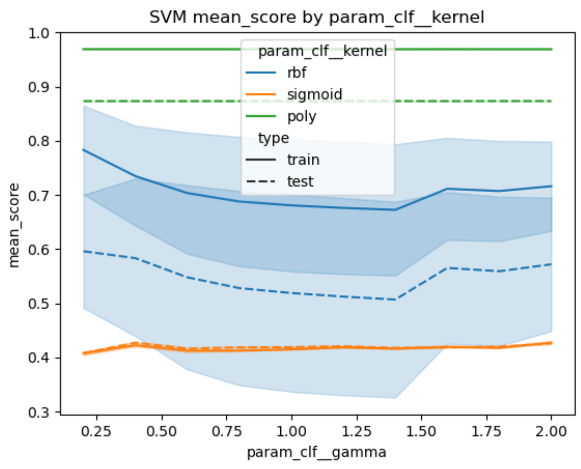
Figure 1: Precursor Performance

	svm	mlp
Index	14	17
mean_fit_time	202.34075051546097	55.17197638750076
std_fit_time	14.47178747999084	7.04162247686103
mean_score_time	15.70475322008133	0.11756110191345215
std_score_time	0.6972991599382162	0.006086672389377183
params	{'clf__C': 0.2, 'clf__gamma': 1.0, 'clf__kerne...	{'clf__alpha': 0.0001, 'clf__hidden_layer_size...
split0_test_score	0.8664	0.9012
split1_test_score	0.8676	0.9012
split2_test_score	0.8816	0.9024
split3_test_score	0.8784	0.8968
mean_test_score	0.8735	0.9004000000000001
std_test_score	0.006611353870426251	0.00213541565040624
rank_test_score	1	1
split0_train_score	0.9714666666666667	0.9998666666666667
split1_train_score	0.9632	1.0
split2_train_score	0.9713333333333334	1.0
split3_train_score	0.9708	1.0
mean_train_score	0.9692000000000001	0.9999666666666667
std_train_score	0.003473071007368331	5.773502691895622e-05
best_final_test	0.838	0.8932
best_cv_test	0.8735	0.9004000000000001
best_cv_train	0.9692000000000001	0.9999666666666667

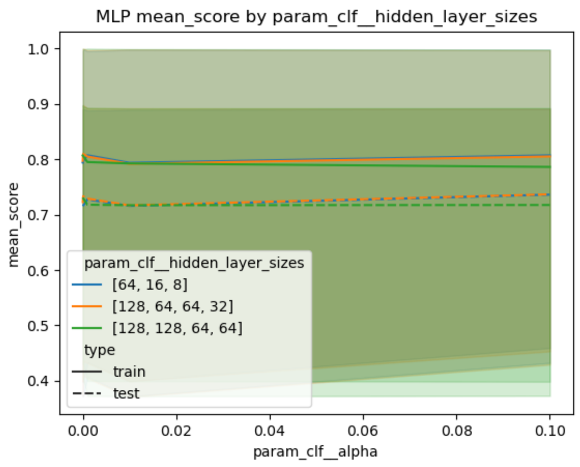
Table 1: Best Results and MetaData



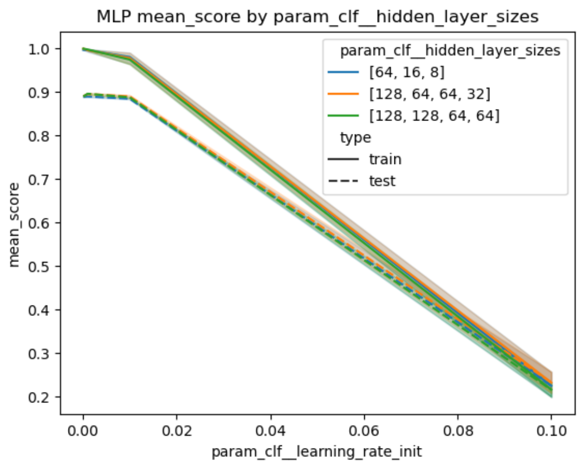
(a) SVM performance by C



(b) SVM performance by gamma

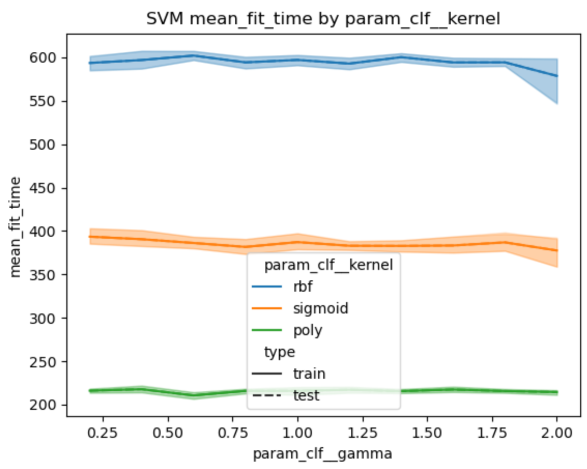


(c) MLP performance by alpha

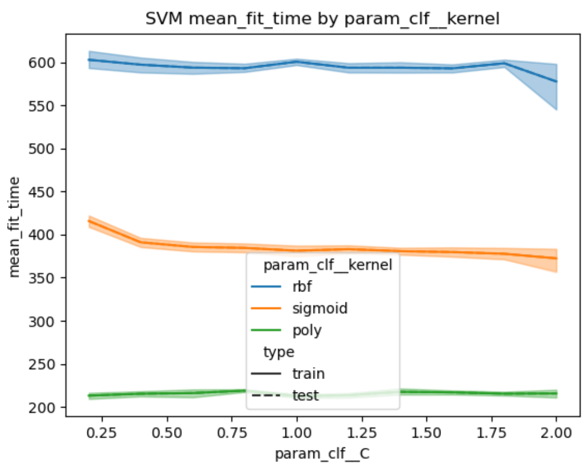


(d) MLP performance by learning rate

Figure 2: Full Data Search



(a) SVM Compute time by Gamma



(b) SVM compute time by C

Figure 3: Training time

3.1 SVM Discussion

I want to take a second and talk about how surprised I was that the polynomial model was the best, especially with the most simple degree. I was quite surprised to see that the legendary Radial Basis Function was so cleanly toppled, until I took a look at the compute times in 3. Looking back on the text output of the training cell, I can see that a great many models timed out before they converged since I set the max iterations of the model to be 500. Moreover, we can see that the polynomial kernel was fit consistently the fastest. I think that this is evidence to support the idea that the polynomial kernel may not have necessarily been the best model for the job, just the model that converged the fastest to their real optimal performance.

4 Test Results

The test results are also included in Table 1 in a manner that is consistent with all of my submissions this year, since I am just using the same function. Interestingly, we can see that the MLPNet classifier outperformed the svm classifier in every single metric I provided. I will take a moment to explicitly list all of the things that the MLPNet beat the SVM on: Fit time, Score time, mean training score, training score consistency, mean validation score, validation score consistency, final test score, and generalization.

It is quite jarring just how solidly the MLPNet classifier out performed the SVM classifier, even with such a simple model. This model doesn't utilize any convolutional layers for feature extraction, and yet it is vastly superior to the svm model. While I am not surprised that the MLPNet outperformed the SVM, I think that the degree with which it is outperforming is likely connected to the previously mentioned lack of covergence from the SVM classifier for the more classically promising parameters.

4.1 Result examples

To begin, I classified the samples into 4 groups: Both Difficult, Neither Difficult, MLP Difficult, and SVM Difficult. These describe samples which both models missclassified, neither models missclassified, only MLP missclassified, and only SVM missclassified. We can see the requested scatter plot of the relative predicted probabilities of each class with the groups identified by color.

We can see from the scatter plots that the MLPNet classifier was much more likely to strongly assign a negative or positive probability for samples while the SVM was less confident. It seems like trousers are by far the easiest to identify, and that makes sense since they are the only item on this list which does not attempt to cover the torso. It also seems like pullover was the most difficult class, which is fair because even I wouldn't classify things as a pullover most of the time.

classname	type	index	class	svm_proba	svm_call	svm_diff	mlp_proba	mlp_call	mlp_diff	mean_proba
Coat	Both Difficult	4110	4	0.442786	3	True	0.443113	3	True	0.442950
Coat	MLP Difficult	4410	4	0.788874	4	False	0.411459	2	True	0.600166
Coat	SVM Difficult	4695	4	0.498579	2	True	0.999999	4	False	0.749289
Dress	Both Difficult	3441	3	0.316876	0	True	0.493340	0	True	0.405108
Dress	MLP Difficult	3810	3	0.947275	3	False	0.277057	1	True	0.612166
Dress	SVM Difficult	3382	3	0.440828	4	True	0.999520	3	False	0.720174
Pullover	Both Difficult	2801	2	0.399679	4	True	0.485677	4	True	0.442678
Pullover	MLP Difficult	2544	2	0.967783	2	False	0.087898	4	True	0.527840
Pullover	SVM Difficult	2877	2	0.498955	4	True	0.999956	2	False	0.749456
Top	Both Difficult	436	0	0.347538	3	True	0.487817	3	True	0.417677
Top	MLP Difficult	921	0	0.807085	0	False	0.488846	2	True	0.647965
Top	SVM Difficult	137	0	0.429797	3	True	0.983014	0	False	0.706405
Trouser	Both Difficult	1070	1	0.414774	3	True	0.128738	3	True	0.271756
Trouser	MLP Difficult	1914	1	0.815975	1	False	0.236740	3	True	0.526357
Trouser	SVM Difficult	1974	1	0.202755	4	True	1.000000	1	False	0.601378

Table 2: Difficult Items MetaData and Correct Call Probability

classname	type	index	svm_Top	svm_Trouser	svm_Pullover	svm_Dress	svm_Coat	mlp_Top	mlp_Trouser	mlp_Pullover	mlp_Dress	mlp_Coat
Coat	Both Difficult	4110	0.005298	3.400359e-03	0.042683	5.058327e-01	0.442786	2.365100e-08	2.130062e-08	1.573007e-08	5.568867e-01	4.431132e-01
Coat	MLP Difficult	4410	0.030210	1.239151e-02	0.121701	4.682354e-02	0.788874	4.298497e-03	6.602311e-05	5.829506e-01	1.226316e-03	4.114585e-01
Coat	SVM Difficult	4695	0.000140	1.433529e-05	0.501266	6.572349e-07	0.498579	3.423842e-10	1.651771e-09	7.073309e-07	4.242566e-09	9.999993e-01
Dress	Both Difficult	3441	0.634818	8.693196e-03	0.032233	3.168760e-01	0.007380	5.066321e-01	1.002960e-05	1.814361e-05	4.933395e-01	2.181102e-07
Dress	MLP Difficult	3810	0.005804	3.739344e-02	0.003378	9.472747e-01	0.006150	5.968212e-08	7.229427e-01	9.305746e-14	2.770572e-01	1.495911e-15
Dress	SVM Difficult	3382	0.016419	5.340160e-03	0.068409	4.408281e-01	0.469004	6.118283e-10	9.267762e-10	5.577999e-09	9.995196e-01	4.804015e-04
Pullover	Both Difficult	2801	0.010303	6.220486e-03	0.399679	9.726465e-02	0.486532	1.175790e-06	3.336376e-06	4.856768e-01	1.669695e-05	5.143020e-01
Pullover	MLP Difficult	2544	0.000001	4.374569e-07	0.967783	1.306642e-07	0.032215	5.591335e-08	2.054001e-09	8.789789e-02	2.023371e-08	9.121020e-01
Pullover	SVM Difficult	2877	0.000220	1.417864e-04	0.498955	1.571403e-04	0.500526	6.485726e-10	2.794313e-08	9.999561e-01	4.390890e-05	1.202809e-09
Top	Both Difficult	436	0.347538	1.203015e-02	0.117837	4.216860e-01	0.100909	4.878167e-01	3.265101e-10	3.229960e-03	5.089526e-01	7.274153e-07
Top	MLP Difficult	921	0.807085	2.450316e-02	0.096842	6.291166e-02	0.008659	4.888463e-01	5.221946e-06	5.098310e-01	1.317414e-03	4.320292e-10
Top	SVM Difficult	137	0.429797	6.534917e-03	0.007387	5.379585e-01	0.018323	9.830143e-01	1.932584e-04	9.893235e-07	1.679147e-02	2.352449e-08
Trouser	Both Difficult	1070	0.003292	4.147736e-01	0.008784	5.595047e-01	0.013646	7.145541e-06	1.287379e-01	1.998690e-05	8.712345e-01	4.990616e-07
Trouser	MLP Difficult	1914	0.005595	8.159752e-01	0.002692	1.665820e-01	0.009156	1.048266e-11	2.367398e-01	1.773124e-09	7.632602e-01	4.216483e-11
Trouser	SVM Difficult	1974	0.022238	2.027554e-01	0.305108	6.706847e-02	0.402830	3.543663e-12	1.000000e+00	4.664057e-12	3.572991e-08	8.299836e-12

Table 3: Difficult Items Full Calls

Jokes aside, it's pretty clear that the coat vs. pullover distinction is resting primarily on the activation of a center seam or zipper, which is a difficult one to catch on this scale.

As for visualizing some samples of each group, I decided to picture the image for each combination of class and difficulty type which had the highest average confidence. I decided that it would likely be more interesting to look at the images which evoked some genuine misunderstanding from our models, rather than randomly selected images.

My discussion of these items will (mostly) go in order of the table, which correlates to the reading order of the grid of images. I will not cover every single image, since that will result in far more verbosity than I want to write and you want to read.

Starting off with the first image of Both Difficult Coat, neither of our models were very confident. They both called this one a dress, which I'd say is a valid interpretation. I don't think I would've noticed this image is a coat if I'm honest. However, when I consulted my wife she immediately identified it as a coat without even being prompted on what classes we can choose from, so possibly my personal fashion ability needs more training data.

Moving on to MLP Difficult Coat, this is likely due to the behavior I discussed earlier about how coats will look like pullovers with a seam in the middle. This item's seam is very small and poorly rendered, and the image shows some strange noise at the bottom. As such, MLPNet called this a pullover likely due to it's sensitivity, where these small errors weren't enough to throw off the less sensitive SVM.

Skipping to Both Difficult Dress, I highly suspect the design of the dress around the chest which has been absolutely murdered by compression threw off both of them. Very few details can be made out at all from this image which out models likely relied on.

Skipping to SVM Difficult Dress, I believe the horizontal line pattern caused the SVM to say that this is a coat. This actually makes a lot of sense to me because I see way more coats with this kind of pattern than I do dresses. MLPNet is sensitive enough to draw a conclusion from the shape of the

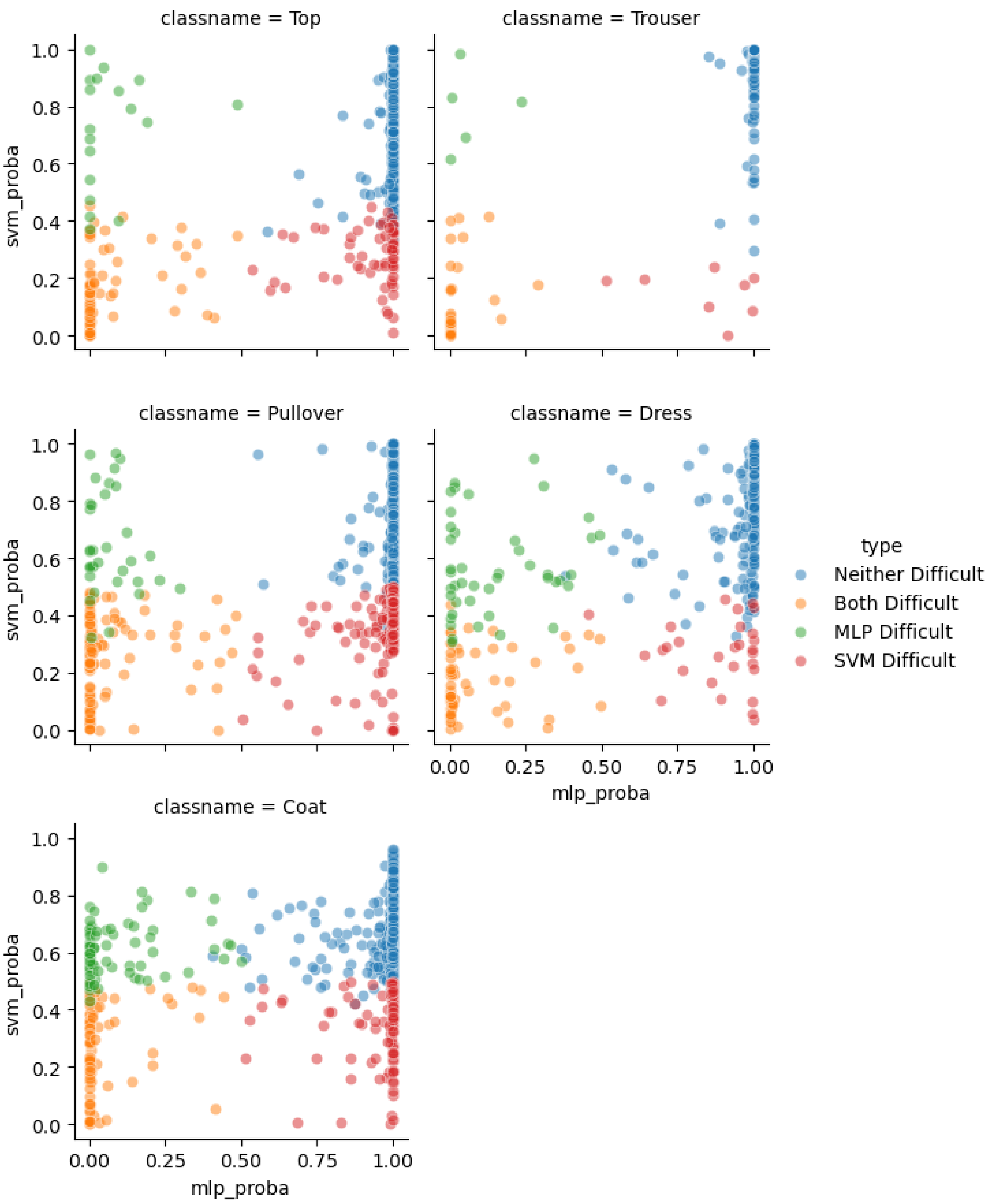


Figure 4: Probability Correlation

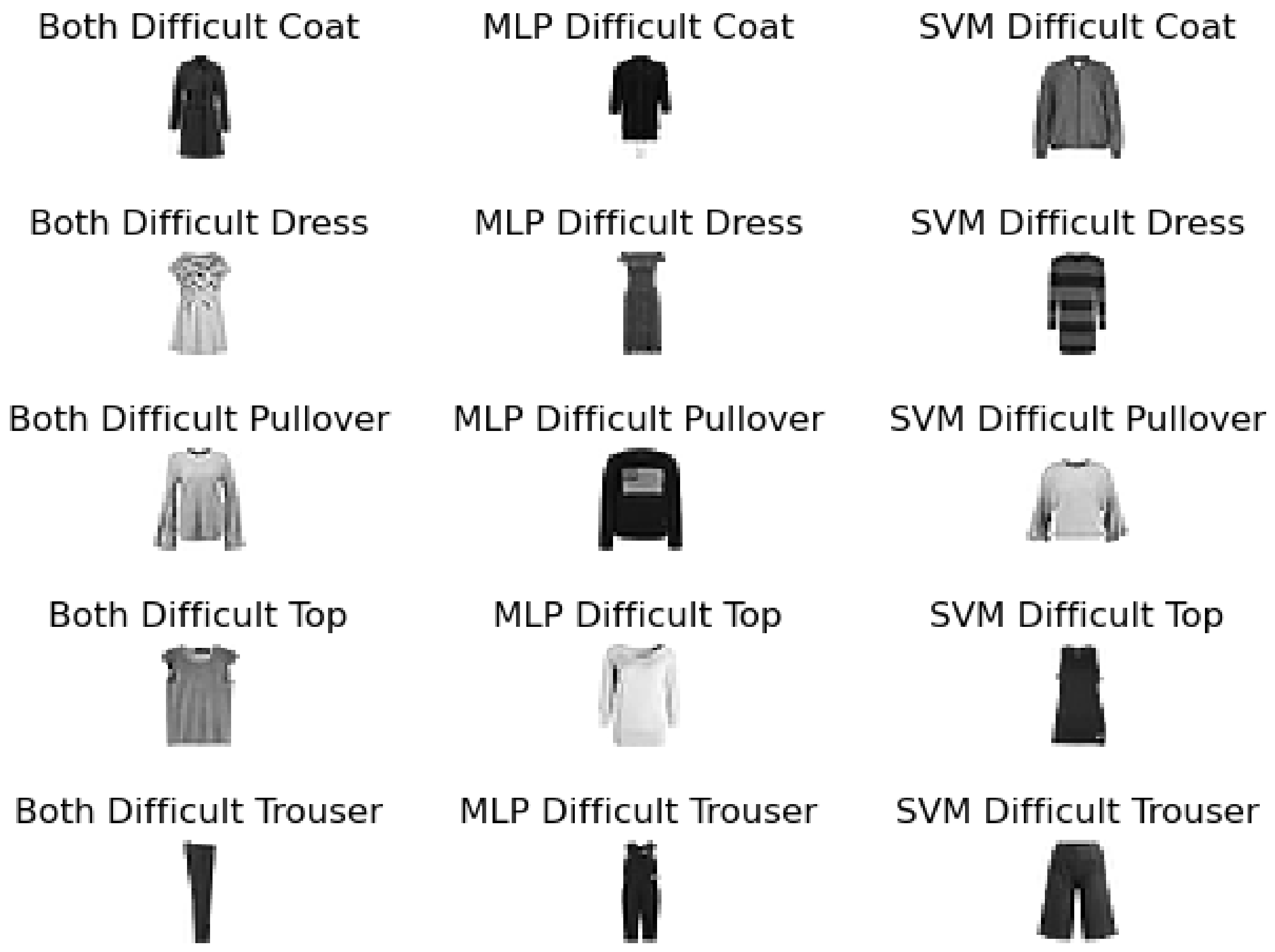


Figure 5: Example Misses

item, while the SVM likely was thrown off by the lines.

Skipping down to MLP Difficult Pullover, I think it's obviously the american flag that's being difficult here. The MLP classifier had no idea how to handle this, and somehow that ended up with it being a coat. I wonder if this sample set is biased towards having more coats with designs than pullovers. This error would require more in-depth research to debug. Possibly it's more common to put a flag on a coat than a pullover.

Skipping down to Both Difficult Top, I think that the wavy folds and lack of sleaves of the top made this too similar to a dress, which both of out models called. Admittedly, they both gave the Top a pretty high confidence for a missed call, with MLP being almost 50/50 between dress and top.

Skipping to SVM Difficult Trouser, this was classified as a coat by the SVM. My theory as to why is because it expands down from the top, which if we look at SVM Difficult Pullover seems to be a feature that the SVM associated more strongly with coats. I find it more interesting that MLP gave a perfect 100% probability that this image is trousers, which is rare to see.

Finally, for Both Difficult Trouser... I have to agree with the models on this one. These are not pants, this is a pant, singular. This does show evidence that a common feature the SVM and the MLPNet identified is that pants should have 2 legs. I'm quite interested, however, in how confident the SVM was in calling the incorrect item, since the incorrect item overcame a confidence of .41. Looking back at the full probabilities for each item included in Table 3, we can see that this sample had called Dress at .559.