Problem 1:

1a:
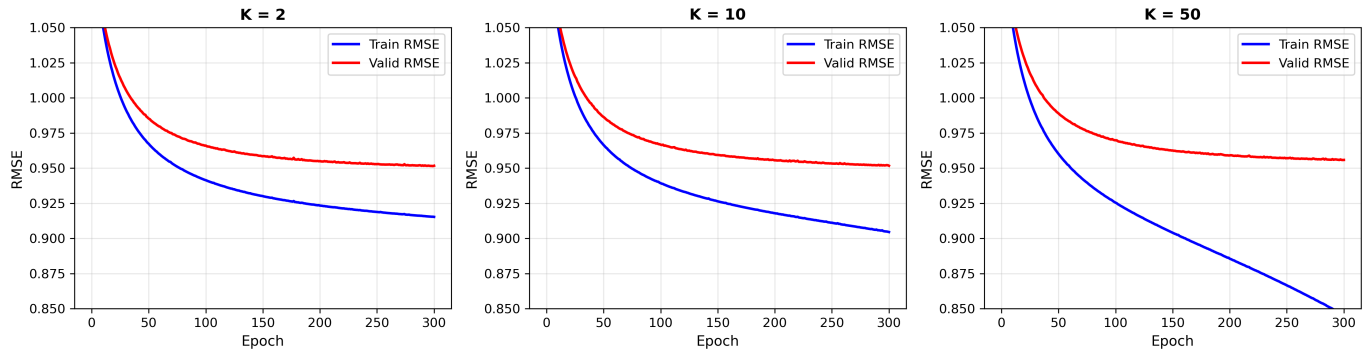

Figure 1: Train and Validation RMSE across epochs. Models were trained with batch size 1000 and step size 0.1 for 300 epochs. As K increases, train RMSE trends to zero faster, however the validation RMSE doesn't drop below 0.95. At K = 50, validation RMSE is highest after 300 epochs. The increasing difference between train and validation RMSE suggests greater overfitting as K increases. K = 2 and K = 10 both provided a min RMSE of 0.9517 which was the lower than the 0.9558 of K = 50. We selected a step size of 0.1, chosen from {0.01, 0.05, 0.1, 0.5 }. The chosen step size balanced the speed of convergence with stability, allowing all models to converge within 300 epochs.
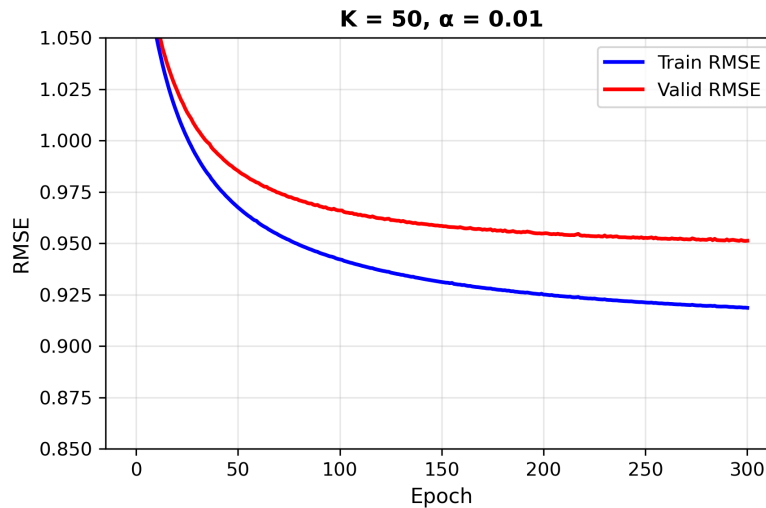
1b:

Figure 2: Train and Validation RMSE with K = 50 and $\alpha = 0.01$. We selected α of 0.01 from {0.001, 0.005, 0.01, 0.05, 0.1}. This value gave the lowest validation RMSE of all values tested. Smaller values showed significant overfitting with high validation RMSE, while values greater than 0.01 overregulized the model and constrained it too much to learn the patterns of the data set. We kept the same step size of 0.1 because it continued to be consistent with speed of convergence and stability of the model. The reegularization did help the validation RMSE getting 0.9512 compared to 0.9558 with $\alpha = 0$. Additionally, the regularized graph shows a smaller gap between train and validation RMSE, indicating better generalization.

Model	Train		Validation		Test	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
LF K = 2, $\alpha = 0$	0.9153	0.7252	0.9517	0.7542	0.9455	0.747
LF K = 10, $\alpha = 0$	0.9045	0.7161	0.9517	0.753	0.946	0.7469
LF K = 50, $\alpha = 0$	0.8453	0.6701	0.9558	0.756	0.9512	0.749
LF K = 50, $\alpha = 0.01$	0.9186	0.7274	0.9512	0.7534	0.9451	0.7463

Table 1: Performance comparison of models trained with batch size 1000, step size 0.1 for 300 epochs. RMSE and MAE reported for train validation and test.

1c:

Based on validation RMSE, K = 10 gives strong results without a super complex model. While the K = 50 model achieved an RMSE that was slightly lower, the increase in model complexity and training time is not worth the minor improvement. This model's train RMSE is also closer to the validation RMSE than K = 2, indicating it generalizes better. Looking at MAE over RMSE, the K = 10 model outperforms all other models on validation, suggesting it is still the strongest pick. No model showed any significant difference in RMSE versus MAE, however the relative ordering changes slightly, favoring the K = 10 model.
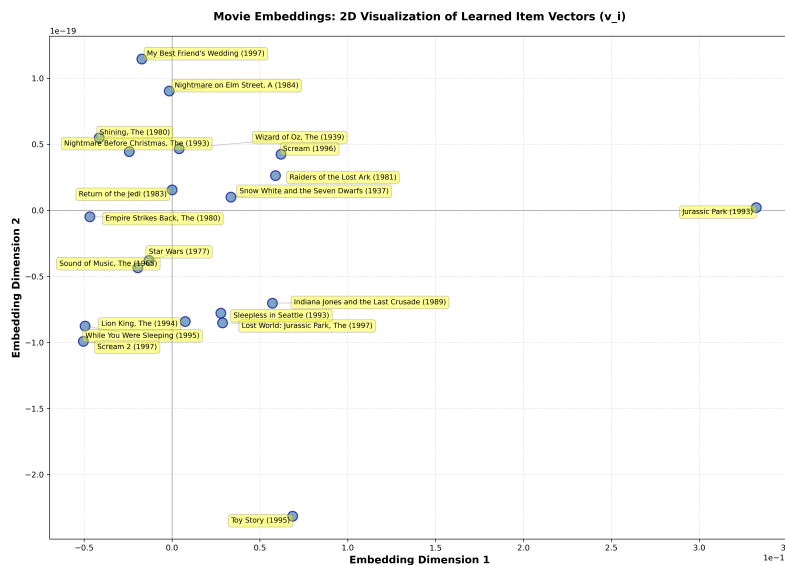
1d:

Figure 3: There does not seem to be any strong correlation between the points in the scatterplot. The only connection is all of the starwars movies being near each other, and the movies with scary titles being located near the top left of the graph. The lack of clustering suggests that the semantic meaning of the data lies in higher dimensions that cannot be captured in just 2 dimensions. The model uses all 50 dimensions for predictions so the lack of structure in this figure is not representative of poor performance overall.

Problem 2:

2a:

2b:

2c:

2d: