Decoding brain waves to detect hand motion

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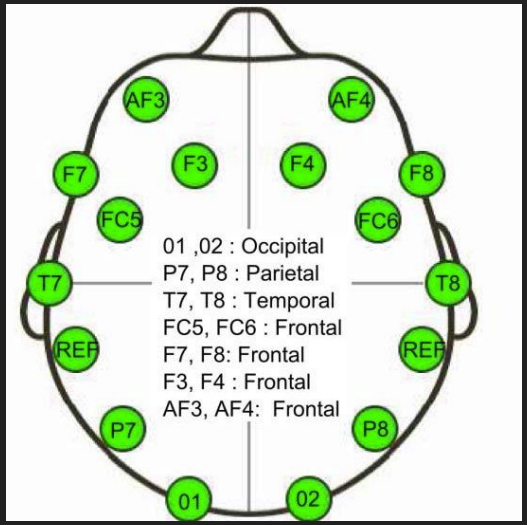
Introduction

- Hand Movement Dataset
  - From Kaggle
  - 112 features - 56 mean readings, 56 std readings
    - alpha, beta, delta, and theta waves from 14 electrode channels
- Models
  - Logistic Regression
  - Support Vector Machines
  - Neural Networks



Logistic Regression

- Polynomial Feature Transformation
- K-fold Cross Validation with Regularization

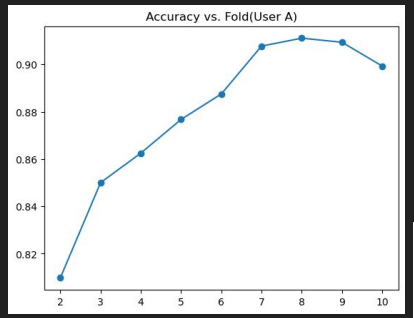
Polynomial Feature Transformation

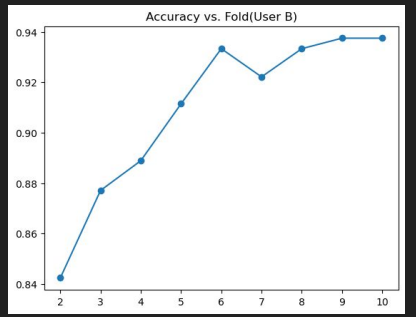
Datasets	Degree = 1	Degree = 2
User A	0.63021	0.85938
User B	0.63715	0.89063
User C	0.50868	0.71181
User D	0.53819	0.84722

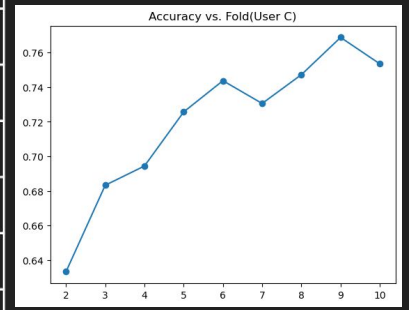
K-Fold CV with L1 Regularization

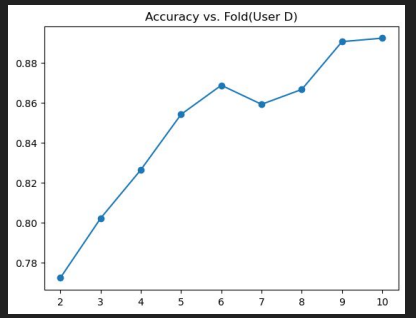
- C = λ^{-1}, 10 values tested from 0.0001 to 10000

	User_a		User_b		User_c		User_d	
K	C	Score	C	Score	C	Score	C	Score
2	0.1	0.80972	100	0.84236	10	0.63333	1000	0.77222
3	10	0.85	100	0.87708	1000	0.68333	1	0.80208
4	10000	0.8625	1	0.88888	0.1	0.69444	100	0.82638
5	1	0.87673	1	0.91145	1000	0.72569	10	0.85416
6	1	0.8875	10	0.93333	1	0.74375	1	0.86875
7	100	0.90776	10	0.92214	1000	0.73058	10	0.85922
8	1	0.91111	10	0.93333	0.01	0.74722	1000	0.86667
9	100	0.90937	1	0.9375	0.1	0.76875	1	0.89063
10	1	0.89930	10	0.9375	10000	0.75347	100	0.89236





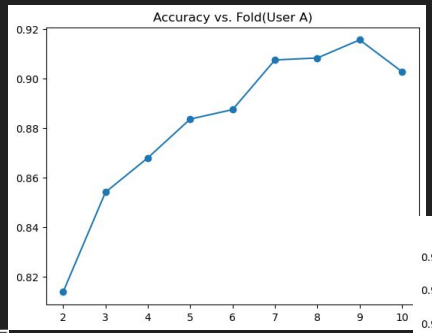


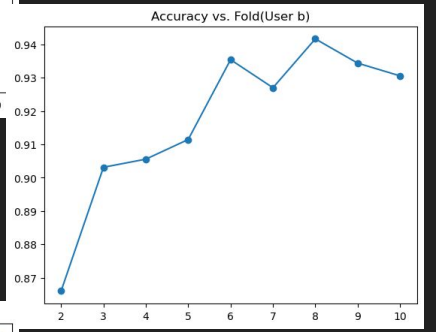


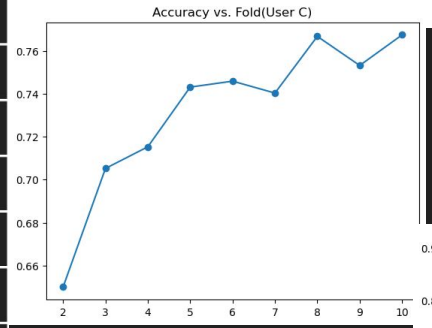
K-Fold CV with L2 Regularization

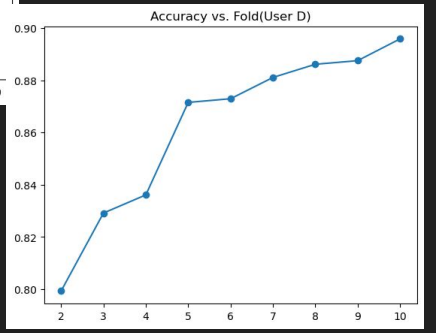
- C = λ^{-1}, 10 values tested from 0.0001 to 10000

	User_a		User_b		User_c		User_d	
K	C	Score	C	Score	C	Score	C	Score
2	0.01	0.81389	0.01	0.86597	1	0.65	0.01	0.79930
3	0.01	0.85416	0.1	0.90313	0.1	0.70520	1	0.82917
4	0.1	0.86805	0.01	0.90556	1	0.71528	0.01	0.83611
5	1	0.88368	0.1	0.91146	10	0.74306	1	0.87152
6	0.1	0.8875	1	0.93542	0.01	0.74583	0.1	0.87292
7	0.1	0.90754	0.1	0.92700	0.01	0.74029	1	0.88107
8	100	0.90833	0.01	0.94166	0.1	0.76667	0.1	0.88611
9	0.01	0.91563	100	0.93438	0.1	0.75313	0.1	0.8875
10	1	0.90278	0.01	0.93056	10000	0.76736	10	0.89583









Logistic Regression - Conclusion

- Best model: 2nd degree polynomial feature transformation with L2 regularization
- Test set accuracy: 0.91563, 0.94166, 0.76667, 0.89583

Support Vector Machines

- Linear Kernel
- Polynomial Kernel

Support Vector Machine: Linear Kernel

	L1 Norm		L2 Norm	
	C	**Score**	**C**	**Score**
User A: Train	1	0.68099	0.1	0.67014
User A: Test	10	0.64583	0.1	0.64063
User B: Train	100	0.71224	1	0.71181
User B: Test	0.01	0.64410	0.01	0.64757
User C: Train	100	0.59071	0.1	0.58681
User C: Test	1	0.50868	0.1	0.51042
User D: Train	100	0.60807	0.1	0.60547
User D: Test	0.1	0.55729	0.001	0.55208

Support Vector Machine: Polynomial Kernel

Datasets	Training		Test	
Users	Degree	Score	Degree	Score
User A	3	0.84983	2	0.73438
User B	3	0.96658	3	0.86458
User C	3	0.82204	3	0.61631
User D	2	0.89583	2	0.76736

K-Fold Cross Validation

K	User A		User B		User C		User D	
	Degree	Score	Degree	Score	Degree	Score	Degree	Score
2	2	0.72152	3	0.79722	3	0.56388	3	0.72291
3	2	0.75625	3	0.87187	3	0.62083	3	0.76979
4	2	0.775	3	0.88055	3	0.62222	3	0.79444
5	2	0.77951	3	0.90104	3	0.64583	3	0.80902
6	3	0.79583	3	0.90416	3	0.65833	3	0.8125
7	2	0.79318	3	0.90510	3	0.64563	3	0.82281
8	3	0.8	3	0.90833	3	0.65277	3	0.82777
9	3	0.80625	3	0.90625	3	0.675	3	0.83125
10	3	0.80208	3	0.90972	3	0.67361	3	0.83333

Neural Networks

- 60% train, 40% test
- NN structures tried:
  - 112 -> [112] -> 3
  - 112 -> [112, 112, 112] -> 3
  - 112 -> [112, 56, 30, 10] -> 3
  - 56 -> … -> 3
- L2 regularization: lambda in range [0.00001, 1000]

Neural Networks - Best Results

	User A (logistic)	User A (tanh)	User B (logistic)	User B (tanh)	User C (logistic)	User C (tanh)	User D (logistic)	User D (tanh)
Test accuracy	85.1563%	86.8056%	88.6285%	91.4063%	70.4861%	67.1007%	81.3368%	81.5972%
Precision % (0, 1, 2)	83.8, 84.3, 84.0	87.1, 86.3, 84.2	90.5, 85.1, 88.9	84.9, 79.9, 80.1	70.0, 70.0, 61.7	68.2, 66.1, 65.1	83.7, 81.7, 82.5	81.6, 80.4, 79.2
Recall % (0, 1, 2)	86.7, 80.9, 84.4	86.2, 83.3, 88.3	88.6, 88.5, 87.3	85.8, 77.4, 81.7	68.4, 72.6, 60.7	71.0, 68.7, 59.8	82.4, 83.4, 82.2	82.7, 82.4, 76.2

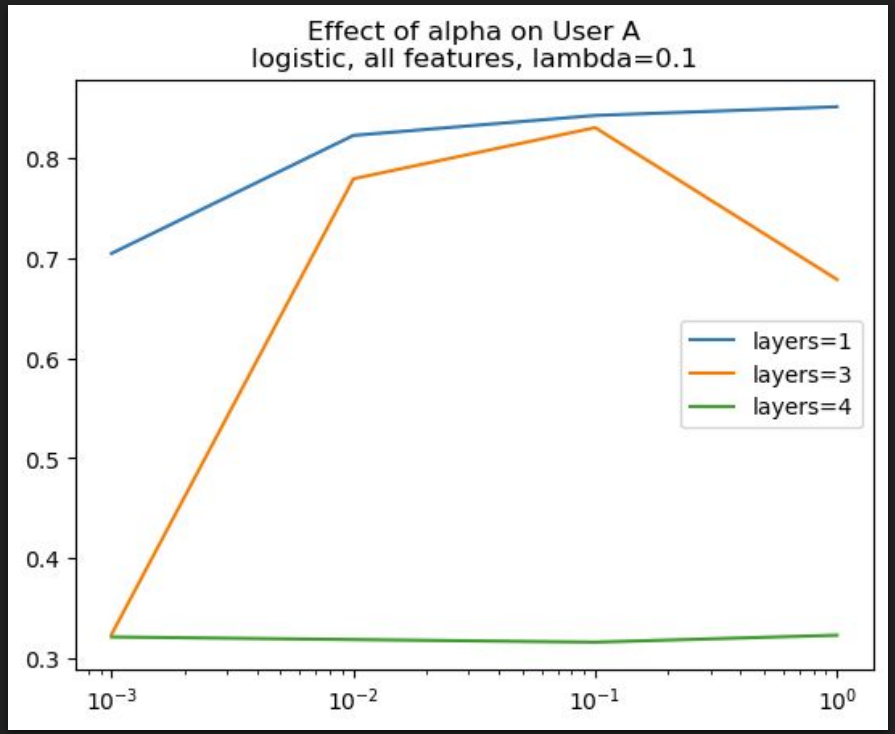
Neural Networks - Best Results

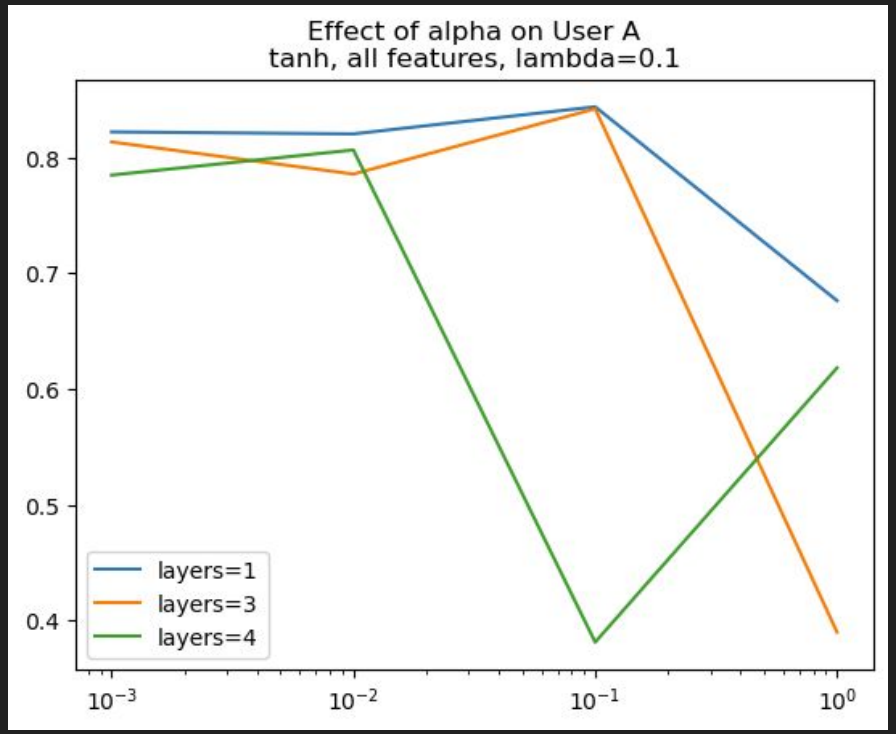
Confusion Matrix	User A	User B	User C	User D
logistic	332 28 23 32 305 40 32 29 331	334 27 16 17 337 27 18 32 344	268 46 78 46 284 61 69 76 224	318 36 38 27 318 29 35 35 316
tanh	332 32 21 27 333 40 22 21 324	337 27 29 36 291 49 24 46 313	274 53 59 56 263 64 72 82 229	305 22 42 33 324 36 36 57 297

Neural Networks - Best Results

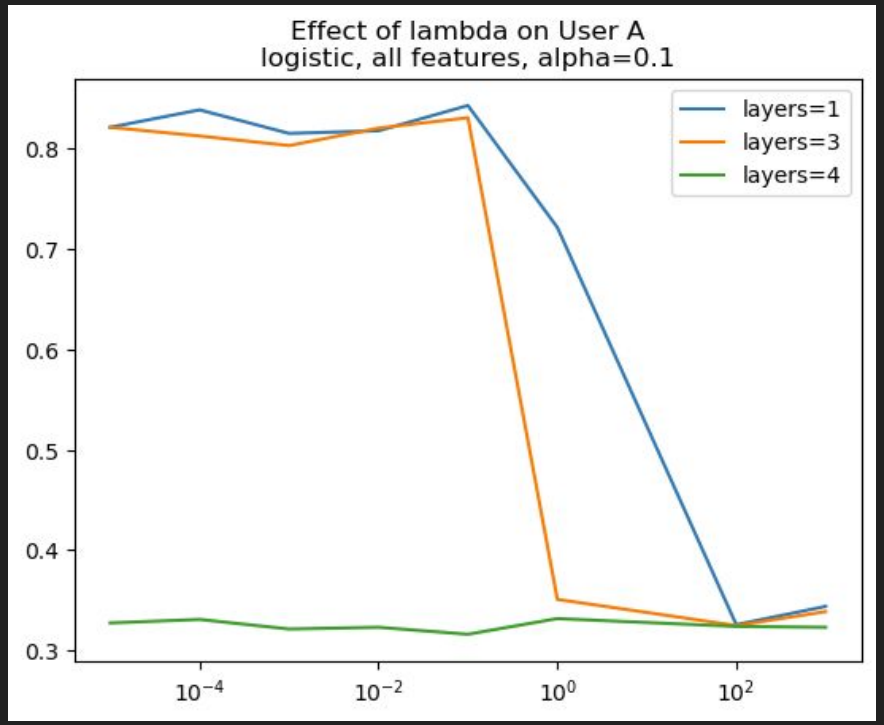
	User A (logistic)	User A (tanh)	User B (logistic)	User B (tanh)	User C (logistic)	User C (tanh)	User D (logistic)	User D (tanh)
Test accuracy	85.1563%	86.8056%	88.6285 %	91.4063 %	70.4861 %	67.1007%	81.3368%	81.5972%
Alpha	1.0	0.1	0.1	1.0	1.0	0.001	1.0	0.01
Lambda	0.1	1.0	0.1	0.1	0.1	1.0	0.1	1.0
Hidden Layer Structure	(112)	(112)	(112, 112, 112)	(112)	(112)	(112)	(112)	(112, 112, 112)
# models above 85% test accuracy	1 (0.1736%)	2 (0.3472%)	22 (3.8194%)	41 (7.1181 %)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

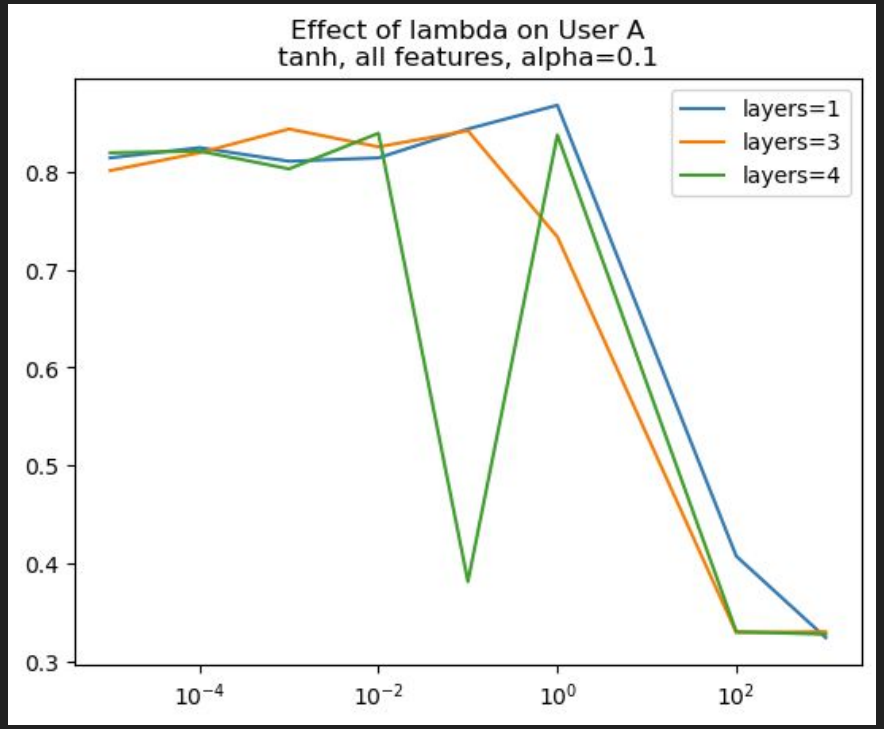
Neural Networks





Neural Networks





Conclusions

User A:

Logistic	SVMs	Neural Networking
0.91944	0.80208	0.86806

User B:

Logistic	SVMs	Neural Networking
0.94166	0.90972	0.91406

User C:

Logistic	SVMs	Neural Networking
0.76667	0.67361	0.70486

User D:

Logistic	SVMs	Neural Networking
0.89583	0.83333	0.81597

Conclusions

- 2nd degree polynomial feature transformation with L2 regularization performed the best
- Dataset is not very linearly separable
- Potential Bottleneck:
  - relatively low sample size
  - Better data pre-processing