Report on
Machine learning sessional Assignment 4

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Implementation Details:

- My primary goal was to create a fast CNN computation program using a very slow programming language.
- I tried to use numpy's vectorized function everywhere I could.
- In the Convolution layer, I used Fast Fourier Transform to multiply two matrices efficiently.
- I processed the image in grayscale format.
- At the beginning some preprocessing is done to image before feeding to the convolution layer.
- It took around 3~4 minutes for 1 epoch with the LeNet-5 model and 30~40 seconds for 1 epoch with the ShNet model.

Model Descriptions:

LeNet-5:

- Input size: 28x28
- Conv2d(out_channels=6,kernel_size=(5,5), stride=1,padding=2)
- ReLU()
- MaxPool2d(kernel_size=(2,2), stride=2)
- ReLU()
- MaxPool2d(kernel_size=(2,2), stride=2)
- FlatteningLayer()
- LinearLayer(out_features=120)
- ReLU()
- LinearLayer(out_features=84)
- ReLU()
- LinearLayer(out_features=10)
- SoftMax()

ShNet (made up name):

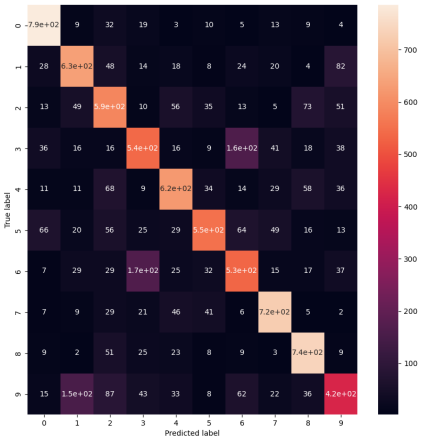
- Input size: 8x8
- Conv2d(out_channels=32,kernel_size=(3,3), stride=(1,1),padding=0)
- ReLU()
- MaxPool2d(kernel_size=(2,2), stride=(2,2))
- FlatteningLayer()

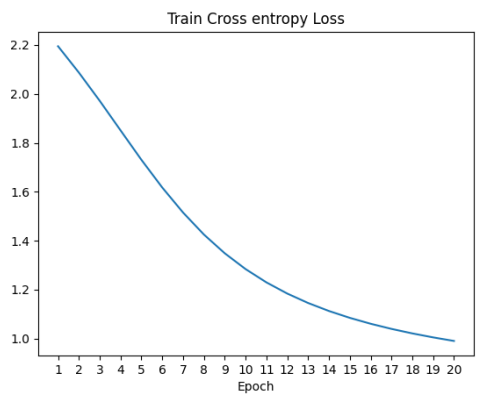
- LinearLayer(out_features=100)
- ReLU()
- LinearLayer(out_features=10)
- SoftMax()

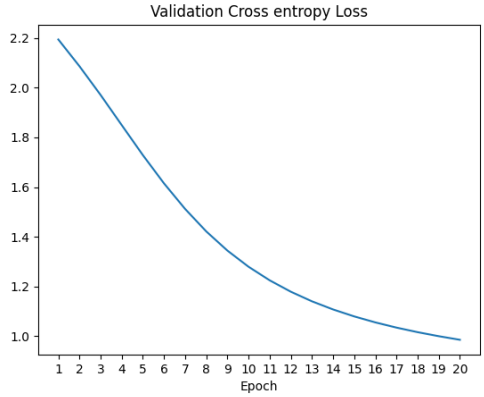
Results on ShNet:

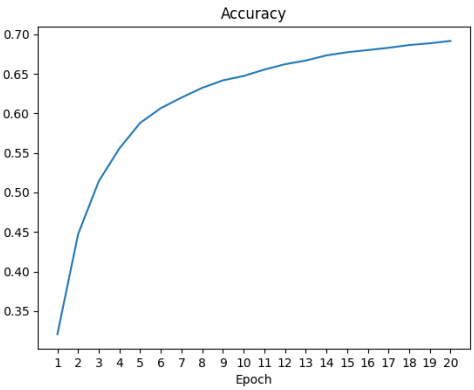
- Learning Rate: 0.001

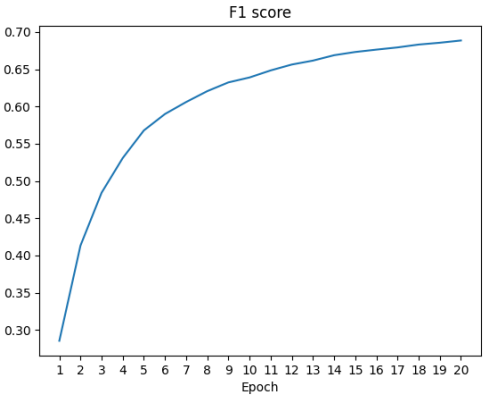
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test
1	2.193594423	2.194945002	0.285459968	0.3207844905	0.3219346834	0.3529519619
2	2.086063065	2.087270013	0.4132579737	0.4472497746	0.461737569	0.4919325266
3	1.97048368	1.971780629	0.4843034374	0.5142019838	0.5388396671	0.5671983865
4	1.849251709	1.850940654	0.5308565327	0.5557935077	0.5884785377	0.6125779245
5	1.728519732	1.730670453	0.567936904	0.5879170424	0.621155426	0.6412724606
6	1.614858793	1.617409235	0.5899965758	0.6066275924	0.6483989555	0.6646497983
7	1.511954787	1.514950328	0.6060693457	0.6199278629	0.6654523543	0.6790429043
8	1.421604331	1.425068845	0.6206685767	0.632213706	0.6778997802	0.6899523286
9	1.344586508	1.34848478	0.6324282914	0.6416816952	0.689693454	0.6997616428
10	1.279609986	1.283842031	0.6390433449	0.6472046889	0.6989707787	0.7077374404
11	1.225044164	1.229508854	0.6484991232	0.6553201082	0.7080952933	0.715713238
12	1.179223584	1.183828687	0.6564052603	0.6620829576	0.7148929504	0.7219471947
13	1.1406066	1.145283175	0.6616612332	0.6667042381	0.7209667679	0.7274477448
14	1.107867509	1.112556892	0.6688994413	0.6732416592	0.7264823444	0.7326732673
15	1.079901444	1.084563378	0.6732331435	0.6771866546	0.7312363219	0.7370737074
16	1.055813655	1.060418872	0.6764100171	0.6800045086	0.7366912056	0.7421158783
17	1.034887002	1.03941358	0.6793771551	0.6828223625	0.7408626936	0.7459662633
18	1.016543405	1.020966018	0.6832182825	0.6863165014	0.7442459644	0.7491749175
19	1.000332869	1.004647626	0.6856603603	0.6885707845	0.7481804172	0.7528419509
20	0.9858892888	0.990102771	0.6886679099	0.6915013526	0.7518523827	0.7563256326







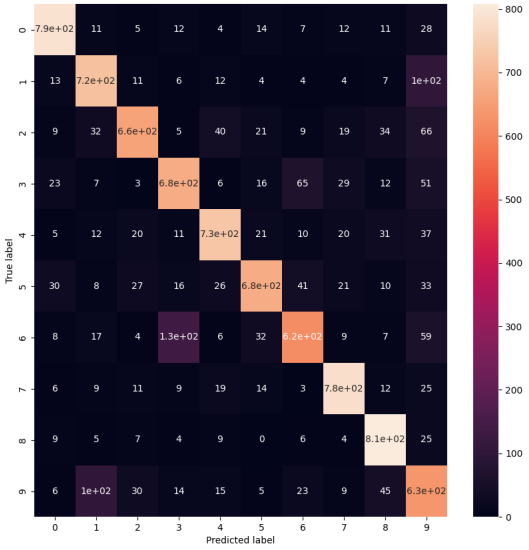


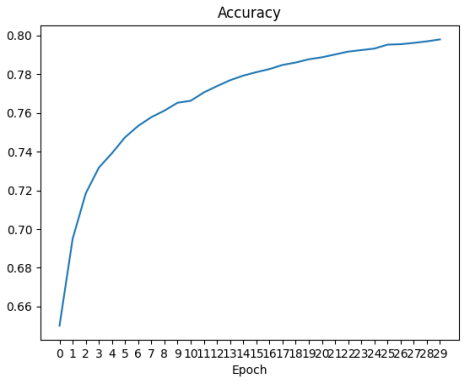


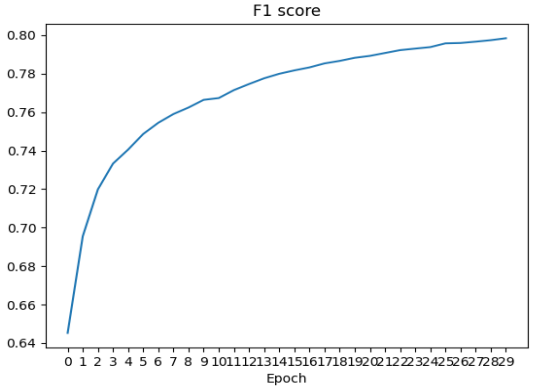
- Learning Rate: 0.01

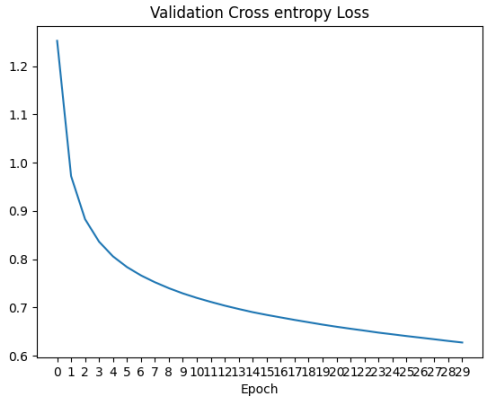
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test
1	1.252481907	1.249699405	0.645281849	0.650135257	0.6962703282	0.7066373304
2	0.9720771757	0.9694552631	0.6955505383	0.6949954914	0.7556702789	0.7594426109

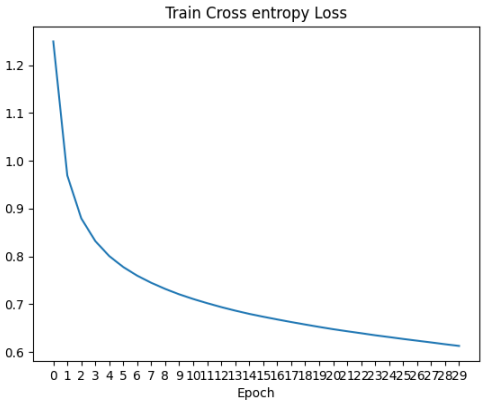
3	0.88282489	0.8797085181	0.7198825776	0.7184400361	0.7813867058	0.783736707
4	0.8362845649	0.8323194625	0.733300557	0.7317403066	0.7963452637	0.7979464613
5	0.805693609	0.8008175279	0.7405667096	0.7391794409	0.8054843127	0.8070223689
6	0.7836285903	0.7779810089	0.7486979789	0.7474075744	0.8120980027	0.8135313531
7	0.7663256199	0.7598541202	0.754523326	0.7532687106	0.8150281677	0.816373304
8	0.7521614574	0.7450323359	0.7590616833	0.7577772768	0.8202014245	0.8214154749
9	0.7398332035	0.7321841432	0.7624545341	0.7611587015	0.8246628684	0.8259075908
10	0.7290219307	0.72088798	0.7664441253	0.7652164112	0.8280168029	0.8292079208
11	0.7197561075	0.7111462186	0.7673610767	0.7662308386	0.8298251908	0.8309497616
12	0.7114160117	0.7023790536	0.7714900826	0.7705139766	0.8311870329	0.8322332233
13	0.7037026587	0.6942010213	0.7746495451	0.7737826871	0.832578069	0.8336083608
14	0.6967292011	0.6868694912	0.7776306028	0.7768259693	0.8355985769	0.8365419875
15	0.6901542016	0.6800270511	0.7799753004	0.7791929666	0.8382846427	0.8392005867
16	0.6845296978	0.6740523452	0.7817421888	0.7809963931	0.8404990341	0.8414008067
17	0.6792861595	0.6684302239	0.7832902548	0.7825743913	0.841530316	0.8424092409
18	0.6740892906	0.6629567122	0.7853800517	0.7847159603	0.8431751654	0.8440594059
19	0.6692306586	0.6577748685	0.7866750939	0.7859558161	0.8450401569	0.8458929226
20	0.6643963529	0.6527409114	0.7882854314	0.7876465284	0.8460676279	0.8469013568
21	0.659954961	0.6480172913	0.7892855645	0.7886609558	0.8475658669	0.8483681702
22	0.6558267559	0.6436778409	0.7907834024	0.7901262399	0.8491522108	0.8499266593
23	0.6519246182	0.639539364	0.7922751453	0.7915915239	0.8500432227	0.8508434177
24	0.6478099448	0.6352754952	0.7930733517	0.792380523	0.8512469962	0.8520352035
25	0.6442970505	0.6315117101	0.7938489734	0.7931695221	0.85219586	0.8529519619
26	0.6406747713	0.627636156	0.7957976309	0.7951983769	0.8537074415	0.8544187752
27	0.6373772284	0.6239599803	0.7959885615	0.7954238052	0.8549005656	0.8556105611
28	0.6339997995	0.6203088065	0.7966752803	0.7961000902	0.8562935766	0.8569856986
29	0.6305212616	0.6165059639	0.7974445	0.7968890893	0.8573266195	0.8579941327
30	0.6272930961	0.613007206	0.7984446614	0.7979035167	0.8583291669	0.8590025669







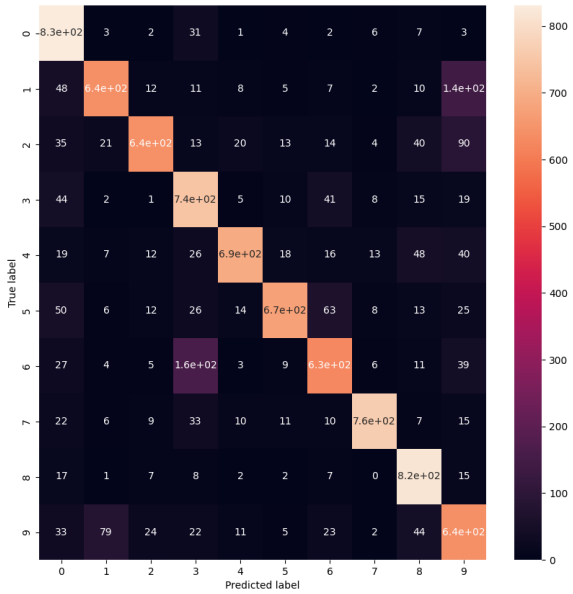


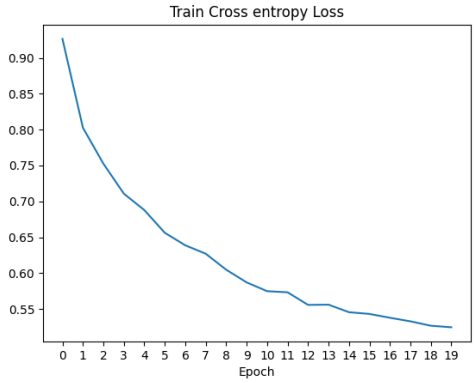


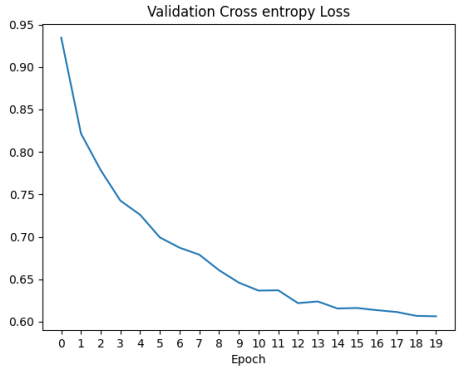
- Learning Rate: 0.1

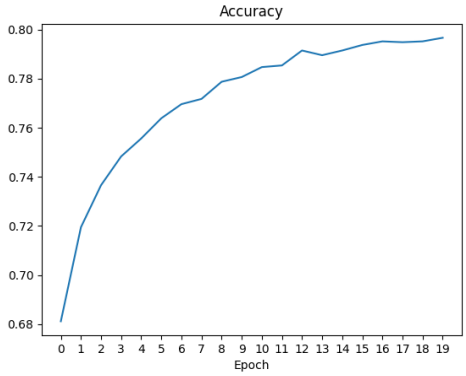
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test

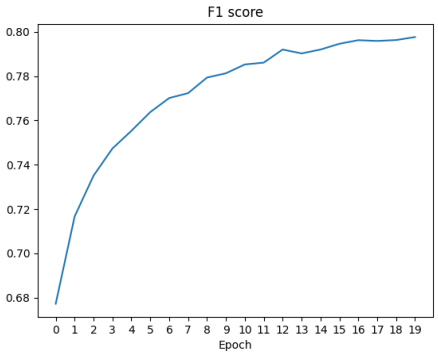
1	0.9345675959	0.9266169239	0.6772434308	0.6811316501	0.761546424	0.7635680235
2	0.8216961359	0.8027251201	0.7166256191	0.7194544635	0.7986413816	0.8006050605
3	0.7785383819	0.7525695535	0.7350414619	0.7365870153	0.8173840672	0.8184818482
4	0.7425416942	0.7107511059	0.7473167197	0.7483092876	0.8297225886	0.8306747341
5	0.7259503152	0.687876668	0.75526292	0.7556357078	0.8392892436	0.8399339934
6	0.6992581154	0.6562277952	0.7637375116	0.7638638413	0.8456196489	0.846259626
7	0.6871837977	0.6387708715	0.7700788031	0.7696122633	0.8481129856	0.848459846
8	0.678960159	0.6270249113	0.7722903637	0.7717538323	0.8512555623	0.8513934727
9	0.6606707459	0.6047390903	0.7793259954	0.77874211	0.8551912684	0.8552438577
10	0.6460814138	0.5870283201	0.7812504926	0.7806582507	0.8585071163	0.8585441878
11	0.6366735548	0.5747776644	0.7852341971	0.7847159603	0.8609193694	0.8609277594
12	0.6370094594	0.5732381886	0.7860731218	0.7853922453	0.8595698835	0.8593692703
13	0.6218990496	0.5556519543	0.7919669856	0.7914788097	0.8614484929	0.8611111111
14	0.6238506551	0.5559901717	0.7902188853	0.7895626691	0.8617266783	0.8614778144
15	0.6156304023	0.5454712947	0.7919641407	0.7914788097	0.8641533948	0.8638613861
16	0.6161458655	0.5430518194	0.794570486	0.7937330929	0.8641287581	0.8638613861
17	0.6135955	0.5377013339	0.7961978161	0.7951983769	0.8637177856	0.8633113311
18	0.6114587588	0.5327520682	0.795852974	0.7948602344	0.8649997481	0.8646864686
19	0.6068988285	0.5265991438	0.7962527636	0.7951983769	0.8649437616	0.8645947928
20	0.6063929786	0.5244864611	0.7976032157	0.796663661	0.8652647213	0.8649614961







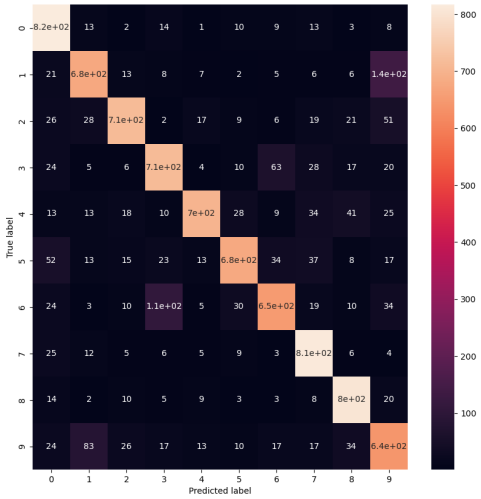


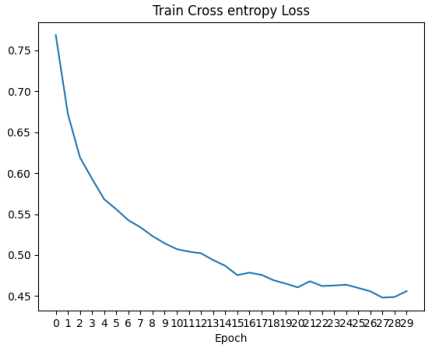


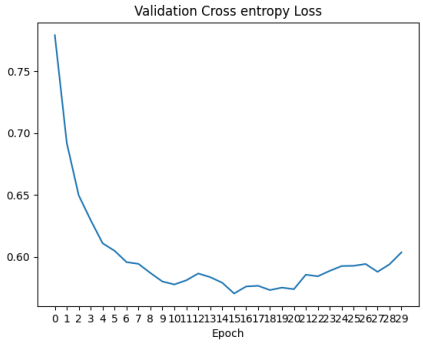
- Learning Rate: 0.2

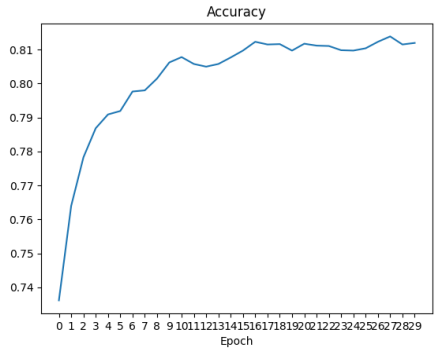
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test
1	0.7790354946	0.7684109989	0.7378515545	0.7361361587	0.7986239522	0.7979464613
2	0.6920700851	0.6721899912	0.7645731462	0.7639765555	0.8304258024	0.83076641
3	0.6497266822	0.6191660346	0.777996803	0.7782912534	0.848971887	0.8498349835
4	0.6297602922	0.5930501601	0.7866339499	0.7868575293	0.8563477519	0.8571690502
5	0.6110834077	0.5681702131	0.7897923218	0.790915239	0.8645931745	0.8656949028
6	0.6050157373	0.5559128859	0.7903381421	0.7919296664	0.865336766	0.8670700403
7	0.5958868117	0.5425160039	0.7966316352	0.7976780884	0.8697262502	0.8708287495
8	0.5944560029	0.5339351927	0.7973314614	0.7980162308	0.870804088	0.8719288596
9	0.5870844108	0.5231337546	0.8014304539	0.8015103697	0.8723907603	0.8729372937
10	0.5802399166	0.5143441095	0.8061653294	0.8062443643	0.8765512217	0.8771543821
11	0.5778457958	0.5073513359	0.8076721566	0.8078223625	0.8744323112	0.8748624862
12	0.5812075911	0.5042330441	0.8052175464	0.8057935077	0.8767186654	0.8772460579
13	0.5867238678	0.5022733567	0.8046210474	0.8050045086	0.8745335278	0.8747708104
14	0.5837425633	0.4939525026	0.8056190488	0.8057935077	0.8757087162	0.8757792446
15	0.5792808329	0.4870102904	0.8072399809	0.8077096483	0.8763387707	0.8766960029
16	0.5705620364	0.4755939095	0.8093291377	0.8097385032	0.8774372609	0.8777044371

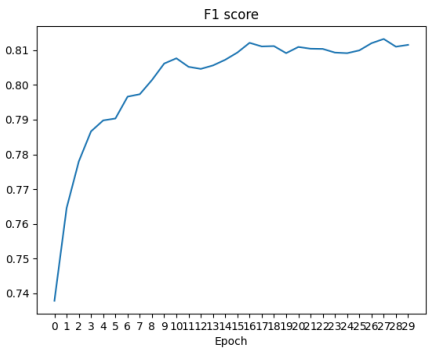
17	0.5762082276	0.4785897092	0.8121315153	0.8123309288	0.8766231941	0.8766960029
18	0.5767821285	0.4759704909	0.8110874965	0.8115419297	0.8765099441	0.8767876788
19	0.5733303827	0.4693310468	0.8111863658	0.8116546438	0.8770198817	0.8773377338
20	0.5753180558	0.465225503	0.809159141	0.8097385032	0.8766377605	0.8768793546
21	0.5740392278	0.4606386869	0.8109373615	0.811767358	0.8768616075	0.8771543821
22	0.5857417188	0.4681091769	0.8104396088	0.8112037872	0.8762501907	0.8765126513
23	0.584441774	0.4623074559	0.8103729791	0.811091073	0.8760785587	0.8762376238
24	0.5888304434	0.4629072433	0.8093246794	0.8098512173	0.8718428121	0.8719288596
25	0.5927281631	0.4639111268	0.8091477598	0.8097385032	0.8741888923	0.8744041071
26	0.5929088974	0.4599299771	0.8099518597	0.8104147881	0.8730942615	0.8732123212
27	0.5943884512	0.4558234696	0.8120241821	0.8123309288	0.8738566054	0.8738540521
28	0.5880600047	0.4481232652	0.8132397507	0.813908927	0.8751602681	0.8753208654
29	0.5941391681	0.4489152788	0.8110152447	0.8115419297	0.873906746	0.8740374037
30	0.6037552429	0.4560181809	0.8115439271	0.8119927863	0.8723122199	0.8724789146







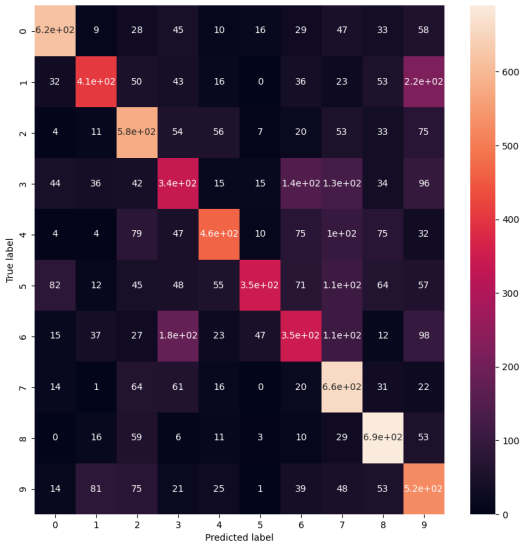


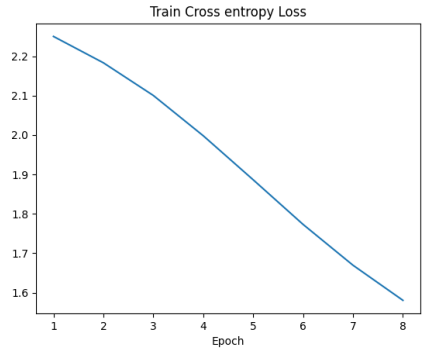


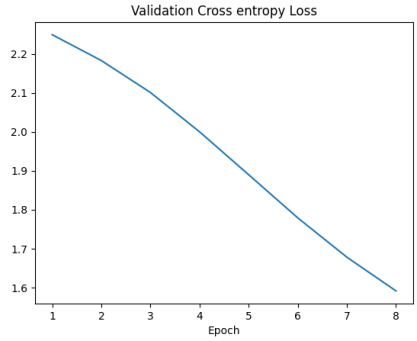
Results on LeNet-5:

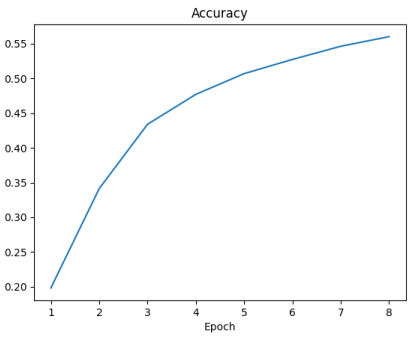
- Learning Rate: 0.001

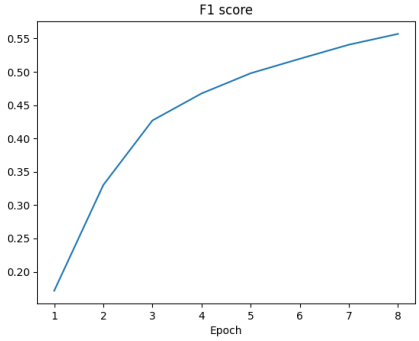
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test
1	2.250029487	2.250275798	0.1715141584	0.1983769161	0.193594265	0.2169966997
2	2.183659257	2.183349892	0.3301573826	0.3414111812	0.3716471983	0.3820132013
3	2.101561291	2.100448269	0.4270113825	0.4339495041	0.4895411477	0.4966079941
4	2.000507953	1.998200739	0.4675405879	0.477006312	0.5458578255	0.5533553355
5	1.890212669	1.886463956	0.4978165703	0.5068755636	0.5832328597	0.5906674001
6	1.779225333	1.773113016	0.5195397963	0.527276826	0.6031236549	0.6100110011
7	1.678161459	1.66948735	0.5406916175	0.5462128043	0.6229467911	0.6284378438
8	1.591431343	1.580413944	0.5568974105	0.5600766456	0.6397495538	0.6442977631







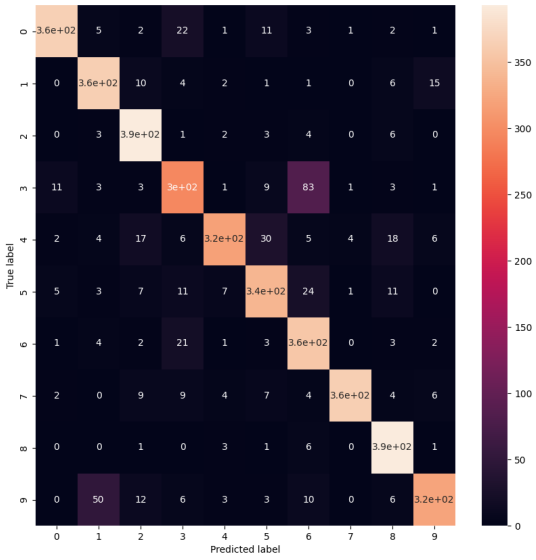


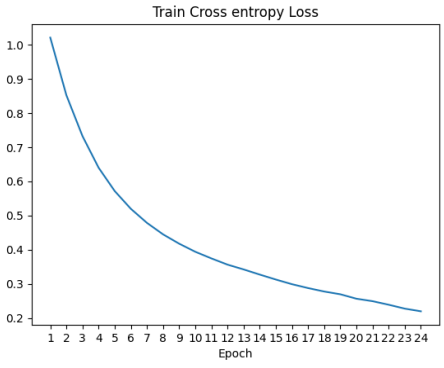


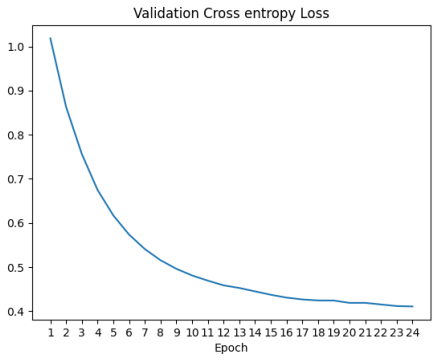
- Learning Rate: 0.01

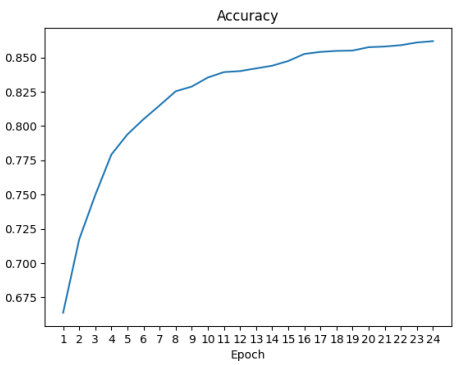
epoch	loss_validation	loss_train	f1_validation	accuracy_validation	f1_test	accuracy_test
1	1.018352527	1.020961986	0.6636977445	0.6638015717	0.7227981277	0.7253392006
2	0.8629478087	0.8523018588	0.7177161979	0.7173379175	0.7684193325	0.7698019802
3	0.7562367002	0.7326322427	0.7498111416	0.7497544204	0.8022928047	0.803630363
4	0.6748281679	0.6401314035	0.7788820447	0.7792239686	0.8267642908	0.8278327833
5	0.6171150953	0.5718504365	0.7935467171	0.7939587426	0.8406865409	0.8414924826
6	0.5737397726	0.5199575567	0.8044777178	0.8050098232	0.853004043	0.8535936927
7	0.5410010626	0.4787841052	0.8143729923	0.8150785855	0.8620648829	0.8624862486
8	0.5155842526	0.4451300104	0.8248449417	0.8253929273	0.8692590398	0.8695452879
9	0.4963452744	0.4178477764	0.8282428957	0.8288310413	0.8733635396	0.8736707004
10	0.4811660092	0.3942085617	0.8350229178	0.8354616896	0.8776351626	0.8778877888
11	0.4694273617	0.3747683138	0.839109922	0.8393909627	0.880468267	0.8806380638
12	0.4587689761	0.3565583992	0.8399142263	0.8401277014	0.8834581602	0.8836633663
13	0.4528181464	0.3425124047	0.8419181333	0.8420923379	0.8854375457	0.8855885589
14	0.4451089361	0.3274403323	0.8438743271	0.8440569745	0.887292624	0.8874220755
15	0.4374376264	0.3129122281	0.8472971964	0.8474950884	0.890467965	0.8906307297
16	0.4309728538	0.2993040819	0.8524349558	0.8526522593	0.8914804792	0.8915474881
17	0.4268764312	0.2879632828	0.8538973933	0.8541257367	0.8925624347	0.8926475981
18	0.4245330649	0.2778682135	0.8546137767	0.8548624754	0.8930494254	0.8931059773

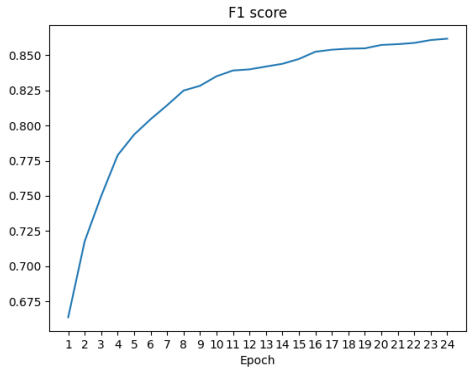
19	0.424366172	0.2698405192	0.8548644822	0.855108055	0.8930494234	0.8931059773
20	0.4190399434	0.2568320618	0.8572620303	0.8575638507	0.8941942548	0.8942977631
21	0.4191433559	0.2496014862	0.8578339032	0.8580550098	0.8944181925	0.8944811148
22	0.4154493752	0.239207285	0.8587140745	0.8590373281	0.8956323644	0.8957645765
23	0.4118470688	0.2278039196	0.8607515691	0.8610019646	0.8967365238	0.8968646865
24	0.4109200742	0.2199711882	0.8617172716	0.8619842829	0.8987443032	0.8988815548











Footnote: Attached pickle file contains implementation of ShNet with 8x8 image input.