Liat Cohen- 205595283

Amit Shakarchy- 313278889

# Deep Learning

# Assignment 1

## network 1 configuration

|  |  |
| --- | --- |
| **parameter** | **value** |
| Network dimensions | [784, 20, 7, 5, 10] |
| Learning rate | 0.009 |
| Validation set size | 20% |
| Stopping criteria | No improvement (or a very small one) for 100 training steps |
| Batch size | 64 |
| Batchnorm | **False** (No batch normalization) |
| Stopping criteria epsilon | **0.0000001** |

Number of iterations and epochs that were needed to train the network: 4400 training steps and 5 epochs

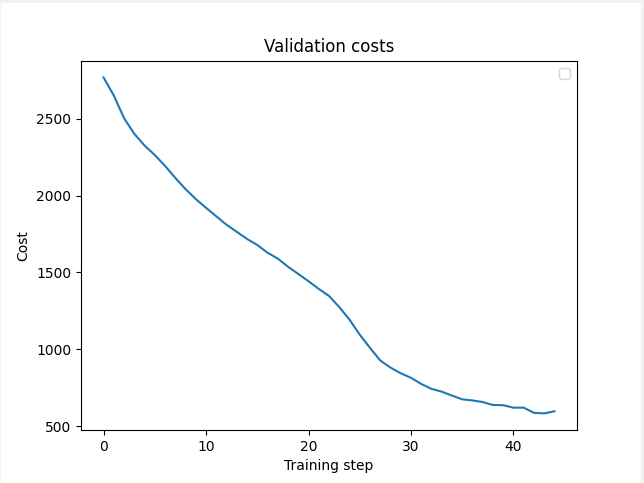
Final accuracy values:

Train- 0.863

Validation- 0.869

Test- 0.868

Cost value for each 100 training steps:



Values from L\_layer\_model output:

Training step #0, validation data: acc - 0.09325, cost - 2769.1112458260077

Training step #100, validation data: acc - 0.10583333333333333, cost - 2651.5893626326806

Training step #200, validation data: acc - 0.15816666666666668, cost - 2503.861065605034

Training step #300, validation data: acc - 0.194, cost - 2402.0919268334274

Training step #400, validation data: acc - 0.2695, cost - 2326.0188366686607

Training step #500, validation data: acc - 0.3065, cost - 2264.018900191718

Training step #600, validation data: acc - 0.3225, cost - 2193.4158686177157

Training step #700, validation data: acc - 0.331, cost - 2115.517815816967

Training step #800, validation data: acc - 0.3428333333333333, cost - 2042.455719037555

Training step #900, validation data: acc - 0.35408333333333336, cost - 1977.6220551681338

Training step #1000, validation data: acc - 0.368, cost - 1921.047478097057

Training step #1100, validation data: acc - 0.4340833333333333, cost - 1865.4403363620029

Training step #1200, validation data: acc - 0.4455, cost - 1810.6078466163185

Training step #1300, validation data: acc - 0.45225, cost - 1764.4878291979235

Training step #1400, validation data: acc - 0.45008333333333334, cost - 1718.3992237110238

Training step #1500, validation data: acc - 0.453, cost - 1678.8637086748513

Training step #1600, validation data: acc - 0.45358333333333334, cost - 1628.7538158337968

Training step #1700, validation data: acc - 0.45516666666666666, cost - 1590.2256547790769

Training step #1800, validation data: acc - 0.52575, cost - 1537.555257991176

Training step #1900, validation data: acc - 0.5530833333333334, cost - 1490.3207104866872

Training step #2000, validation data: acc - 0.5600833333333334, cost - 1443.3116462676685

Training step #2100, validation data: acc - 0.5633333333333334, cost - 1393.0910492287614

Training step #2200, validation data: acc - 0.5684166666666667, cost - 1347.3281566933695

Training step #2300, validation data: acc - 0.5839166666666666, cost - 1275.1684477945848

Training step #2400, validation data: acc - 0.6776666666666666, cost - 1193.4834292546943

Training step #2500, validation data: acc - 0.73175, cost - 1095.245591479115

Training step #2600, validation data: acc - 0.7700833333333333, cost - 1009.4851370132926

Training step #2700, validation data: acc - 0.7869166666666667, cost - 927.6264748116944

Training step #2800, validation data: acc - 0.794, cost - 881.167598466257

Training step #2900, validation data: acc - 0.8064166666666667, cost - 844.1887323518856

Training step #3000, validation data: acc - 0.81475, cost - 814.8851985688696

Training step #3100, validation data: acc - 0.8221666666666667, cost - 774.7932976550704

Training step #3200, validation data: acc - 0.83175, cost - 743.0227696095808

Training step #3300, validation data: acc - 0.83675, cost - 724.5892294440621

Training step #3400, validation data: acc - 0.8395, cost - 699.1791305955458

Training step #3500, validation data: acc - 0.8496666666666667, cost - 674.8574129575242

Training step #3600, validation data: acc - 0.8466666666666667, cost - 667.5298622889991

Training step #3700, validation data: acc - 0.853, cost - 657.167240469644

Training step #3800, validation data: acc - 0.8573333333333333, cost - 637.9268537179688

Training step #3900, validation data: acc - 0.8569166666666667, cost - 636.7019492506076

Training step #4000, validation data: acc - 0.8625, cost - 620.5276208749259

Training step #4100, validation data: acc - 0.8604166666666667, cost - 620.8139441590547

Training step #4200, validation data: acc - 0.86925, cost - 587.0210445190082

Training step #4300, validation data: acc - 0.86925, cost - 583.2817156657345

Training step #4400, validation data: acc - 0.8655833333333334, cost - 597.0095070737353

Running time: 3.579 sec

## network 2 configuration

|  |  |
| --- | --- |
| **parameter** | **value** |
| Network dimensions | [784, 20, 7, 5, 10] |
| Learning rate | 0.009 |
| Validation set size | 20% |
| Stopping criteria | No improvement (or a very small one) for 100 training steps |
| Batch size | 64 |
| Batchnorm | **True** (No batch normalization) |
| Stopping criteria epsilon | **0.000001** |

Number of iterations and epochs that were needed to train the network: 23200 training steps and 30 epochs

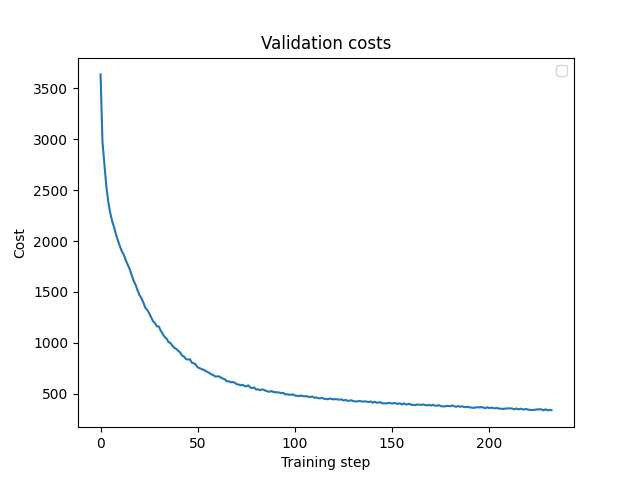
Final accuracy values:

Train- 0.929

Validation- 0.923

Test- 0.928

Cost value for each 100 training steps:



Values from L\_layer\_model output:

Training step #0, validation data: acc - 0.10983333333333334, cost - 3637.8983193136933

Training step #100, validation data: acc - 0.18391666666666667, cost - 2972.4271910362277

Training step #200, validation data: acc - 0.2365, cost - 2748.3573449502715

Training step #300, validation data: acc - 0.27858333333333335, cost - 2532.68855639198

Training step #400, validation data: acc - 0.3145, cost - 2384.490010917342

Training step #500, validation data: acc - 0.33858333333333335, cost - 2273.54870988936

Training step #600, validation data: acc - 0.35983333333333334, cost - 2193.7640162631237

Training step #700, validation data: acc - 0.3740833333333333, cost - 2134.5968575809243

Training step #800, validation data: acc - 0.43166666666666664, cost - 2060.2946727609046

Training step #900, validation data: acc - 0.46441666666666664, cost - 2002.0722027383968

Training step #1000, validation data: acc - 0.47883333333333333, cost - 1945.6149719766458

Training step #1100, validation data: acc - 0.49825, cost - 1898.1048160601258

Training step #1200, validation data: acc - 0.5005, cost - 1864.5106054423893

Training step #1300, validation data: acc - 0.517, cost - 1811.324905913544

Training step #1400, validation data: acc - 0.53175, cost - 1766.7535628107776

Training step #1500, validation data: acc - 0.5425, cost - 1723.610995767601

Training step #1600, validation data: acc - 0.5718333333333333, cost - 1666.4531708415652

Training step #1700, validation data: acc - 0.5908333333333333, cost - 1611.0456214339238

Training step #1800, validation data: acc - 0.59875, cost - 1571.175438110969

Training step #1900, validation data: acc - 0.612, cost - 1518.9614668183663

Training step #2000, validation data: acc - 0.6229166666666667, cost - 1470.3893942507848

Training step #2100, validation data: acc - 0.6279166666666667, cost - 1439.148591407976

Training step #2200, validation data: acc - 0.6433333333333333, cost - 1398.3219032037746

Training step #2300, validation data: acc - 0.6515, cost - 1346.1207634910465

Training step #2400, validation data: acc - 0.6516666666666666, cost - 1324.1138749135998

Training step #2500, validation data: acc - 0.66525, cost - 1291.4178459056386

Training step #2600, validation data: acc - 0.6750833333333334, cost - 1252.995705604194

Training step #2700, validation data: acc - 0.683, cost - 1213.1714720709315

Training step #2800, validation data: acc - 0.6888333333333333, cost - 1193.3849233464746

Training step #2900, validation data: acc - 0.69625, cost - 1161.4376073619028

Training step #3000, validation data: acc - 0.697, cost - 1159.89626024038

Training step #3100, validation data: acc - 0.7014166666666667, cost - 1117.8968337998447

Training step #3200, validation data: acc - 0.7144166666666667, cost - 1086.9582890530214

Training step #3300, validation data: acc - 0.7331666666666666, cost - 1057.7060287381034

Training step #3400, validation data: acc - 0.74725, cost - 1041.5057482202153

Training step #3500, validation data: acc - 0.7740833333333333, cost - 1006.502630885778

Training step #3600, validation data: acc - 0.77125, cost - 998.1373283278424

Training step #3700, validation data: acc - 0.791, cost - 971.3688341741696

Training step #3800, validation data: acc - 0.7969166666666667, cost - 949.7959154933529

Training step #3900, validation data: acc - 0.8015, cost - 939.3023017920216

Training step #4000, validation data: acc - 0.8038333333333333, cost - 922.235528108745

Training step #4100, validation data: acc - 0.8135833333333333, cost - 904.1077875564803

Training step #4200, validation data: acc - 0.8245833333333333, cost - 873.7171831548436

Training step #4300, validation data: acc - 0.82675, cost - 864.2090951534188

Training step #4400, validation data: acc - 0.83575, cost - 839.1278188510225

Training step #4500, validation data: acc - 0.84, cost - 835.5717881612647

Training step #4600, validation data: acc - 0.82425, cost - 838.0844964788533

Training step #4700, validation data: acc - 0.8505, cost - 803.7023590726146

Training step #4800, validation data: acc - 0.8463333333333334, cost - 800.2100618307325

Training step #4900, validation data: acc - 0.8528333333333333, cost - 784.8825398802994

Training step #5000, validation data: acc - 0.8648333333333333, cost - 757.5699062596613

Training step #5100, validation data: acc - 0.8595833333333334, cost - 751.5357463192437

Training step #5200, validation data: acc - 0.8663333333333333, cost - 741.1348744936563

Training step #5300, validation data: acc - 0.86625, cost - 735.4281361619876

Training step #5400, validation data: acc - 0.8685833333333334, cost - 724.416217945361

Training step #5500, validation data: acc - 0.87175, cost - 713.4483607595128

Training step #5600, validation data: acc - 0.8729166666666667, cost - 704.1880274236873

Training step #5700, validation data: acc - 0.8736666666666667, cost - 689.4261330819222

Training step #5800, validation data: acc - 0.8766666666666667, cost - 684.1499896874192

Training step #5900, validation data: acc - 0.87875, cost - 668.8052696395896

Training step #6000, validation data: acc - 0.8789166666666667, cost - 670.1324324307427

Training step #6100, validation data: acc - 0.8749166666666667, cost - 670.0435830332711

Training step #6200, validation data: acc - 0.8803333333333333, cost - 658.2657665674376

Training step #6300, validation data: acc - 0.88375, cost - 647.9834071679976

Training step #6400, validation data: acc - 0.8808333333333334, cost - 640.6305755781198

Training step #6500, validation data: acc - 0.887, cost - 622.1527900313864

Training step #6600, validation data: acc - 0.88575, cost - 621.0523189299063

Training step #6700, validation data: acc - 0.8888333333333334, cost - 612.7764943851319

Training step #6800, validation data: acc - 0.8885833333333333, cost - 613.9208593514172

Training step #6900, validation data: acc - 0.8886666666666667, cost - 609.4528356545666

Training step #7000, validation data: acc - 0.8936666666666667, cost - 593.8272733142182

Training step #7100, validation data: acc - 0.89225, cost - 590.3263044565258

Training step #7200, validation data: acc - 0.89375, cost - 582.0508886346116

Training step #7300, validation data: acc - 0.8904166666666666, cost - 588.2094069870045

Training step #7400, validation data: acc - 0.8935833333333333, cost - 575.4371907593516

Training step #7500, validation data: acc - 0.8948333333333334, cost - 571.9625549577197

Training step #7600, validation data: acc - 0.88825, cost - 582.0474999936918

Training step #7700, validation data: acc - 0.8953333333333333, cost - 561.8505312650303

Training step #7800, validation data: acc - 0.8961666666666667, cost - 555.2002336479259

Training step #7900, validation data: acc - 0.8936666666666667, cost - 561.7615684708842

Training step #8000, validation data: acc - 0.8988333333333334, cost - 541.8742690456586

Training step #8100, validation data: acc - 0.8979166666666667, cost - 543.0695609299288

Training step #8200, validation data: acc - 0.8989166666666667, cost - 535.5555544410407

Training step #8300, validation data: acc - 0.8970833333333333, cost - 541.9194834889297

Training step #8400, validation data: acc - 0.8965833333333333, cost - 538.9146905912839

Training step #8500, validation data: acc - 0.8990833333333333, cost - 528.4452955599407

Training step #8600, validation data: acc - 0.9005833333333333, cost - 522.6813311876372

Training step #8700, validation data: acc - 0.8999166666666667, cost - 518.8047906502923

Training step #8800, validation data: acc - 0.898, cost - 526.4095931298895

Training step #8900, validation data: acc - 0.9006666666666666, cost - 516.1954170122618

Training step #9000, validation data: acc - 0.9016666666666666, cost - 514.8686673673044

Training step #9100, validation data: acc - 0.9004166666666666, cost - 513.8512746698397

Training step #9200, validation data: acc - 0.8996666666666666, cost - 511.89320038339866

Training step #9300, validation data: acc - 0.9021666666666667, cost - 505.3846154252493

Training step #9400, validation data: acc - 0.9004166666666666, cost - 508.71382848390493

Training step #9500, validation data: acc - 0.9033333333333333, cost - 493.2889594458773

Training step #9600, validation data: acc - 0.90325, cost - 494.6700718243578

Training step #9700, validation data: acc - 0.905, cost - 490.74058744806234

Training step #9800, validation data: acc - 0.90375, cost - 489.4270435720947

Training step #9900, validation data: acc - 0.903, cost - 493.4466859387361

Training step #10000, validation data: acc - 0.90425, cost - 481.3538532971476

Training step #10100, validation data: acc - 0.9055, cost - 480.29069854947346

Training step #10200, validation data: acc - 0.9073333333333333, cost - 475.30576664283535

Training step #10300, validation data: acc - 0.90425, cost - 482.08333253400633

Training step #10400, validation data: acc - 0.90525, cost - 476.7321924510444

Training step #10500, validation data: acc - 0.9068333333333334, cost - 474.8001316060786

Training step #10600, validation data: acc - 0.904, cost - 475.96200964993477

Training step #10700, validation data: acc - 0.9069166666666667, cost - 469.5102862539067

Training step #10800, validation data: acc - 0.90725, cost - 468.6116435013667

Training step #10900, validation data: acc - 0.9049166666666667, cost - 471.778806883431

Training step #11000, validation data: acc - 0.908, cost - 459.62525444936784

Training step #11100, validation data: acc - 0.9069166666666667, cost - 463.36338729217516

Training step #11200, validation data: acc - 0.91025, cost - 455.3397572982814

Training step #11300, validation data: acc - 0.90825, cost - 454.6176738255898

Training step #11400, validation data: acc - 0.9086666666666666, cost - 459.36216190150736

Training step #11500, validation data: acc - 0.909, cost - 449.7571296854653

Training step #11600, validation data: acc - 0.9095, cost - 447.46740188739534

Training step #11700, validation data: acc - 0.9105, cost - 445.9566313797037

Training step #11800, validation data: acc - 0.9073333333333333, cost - 452.74636678926356

Training step #11900, validation data: acc - 0.9095833333333333, cost - 447.8347687504032

Training step #12000, validation data: acc - 0.911, cost - 445.01238835613015

Training step #12100, validation data: acc - 0.9094166666666667, cost - 446.44350375235956

Training step #12200, validation data: acc - 0.90925, cost - 444.4464566305031

Training step #12300, validation data: acc - 0.9115833333333333, cost - 440.43152815437725

Training step #12400, validation data: acc - 0.9099166666666667, cost - 445.40618091996237

Training step #12500, validation data: acc - 0.91175, cost - 432.5683068760794

Training step #12600, validation data: acc - 0.9095833333333333, cost - 439.4744799554158

Training step #12700, validation data: acc - 0.9133333333333333, cost - 430.6559151014749

Training step #12800, validation data: acc - 0.9113333333333333, cost - 431.16495858956944

Training step #12900, validation data: acc - 0.9114166666666667, cost - 436.132532248659

Training step #13000, validation data: acc - 0.9119166666666667, cost - 426.9342401960045

Training step #13100, validation data: acc - 0.9125, cost - 425.17834870902095

Training step #13200, validation data: acc - 0.9149166666666667, cost - 422.6427007564025

Training step #13300, validation data: acc - 0.9123333333333333, cost - 428.8188569001942

Training step #13400, validation data: acc - 0.9125, cost - 426.18828587213574

Training step #13500, validation data: acc - 0.914, cost - 422.1389678828108

Training step #13600, validation data: acc - 0.91175, cost - 425.2730800675934

Training step #13700, validation data: acc - 0.91275, cost - 421.4061915984277

Training step #13800, validation data: acc - 0.91475, cost - 418.10637288235904

Training step #13900, validation data: acc - 0.9124166666666667, cost - 424.47355958365733

Training step #14000, validation data: acc - 0.9153333333333333, cost - 412.16615641703027

Training step #14100, validation data: acc - 0.9125, cost - 421.05103012394676

Training step #14200, validation data: acc - 0.9158333333333334, cost - 411.9757486528453

Training step #14300, validation data: acc - 0.91475, cost - 412.1207788903973

Training step #14400, validation data: acc - 0.9120833333333334, cost - 417.31877385335

Training step #14500, validation data: acc - 0.9154166666666667, cost - 404.7663705537844

Training step #14600, validation data: acc - 0.9148333333333334, cost - 406.02109508919443

Training step #14700, validation data: acc - 0.9179166666666667, cost - 403.63854795706277

Training step #14800, validation data: acc - 0.915, cost - 409.8491319257735

Training step #14900, validation data: acc - 0.9149166666666667, cost - 407.2771147666969

Training step #15000, validation data: acc - 0.9169166666666667, cost - 403.4419906444019

Training step #15100, validation data: acc - 0.9141666666666667, cost - 408.0663567222401

Training step #15200, validation data: acc - 0.9138333333333334, cost - 404.7497437045849

Training step #15300, validation data: acc - 0.91725, cost - 399.28759322620215

Training step #15400, validation data: acc - 0.9155, cost - 406.34399322305654

Training step #15500, validation data: acc - 0.9191666666666667, cost - 394.13131796153704

Training step #15600, validation data: acc - 0.91375, cost - 404.70888649504957

Training step #15700, validation data: acc - 0.9176666666666666, cost - 394.907742628554

Training step #15800, validation data: acc - 0.9161666666666667, cost - 395.69290487148373

Training step #15900, validation data: acc - 0.9151666666666667, cost - 400.9365523908018

Training step #16000, validation data: acc - 0.918, cost - 390.77818915822303

Training step #16100, validation data: acc - 0.9171666666666667, cost - 390.0671178893099

Training step #16200, validation data: acc - 0.92075, cost - 387.155161228883

Training step #16300, validation data: acc - 0.9175, cost - 394.4422912634471

Training step #16400, validation data: acc - 0.9161666666666667, cost - 391.44633093671007

Training step #16500, validation data: acc - 0.91825, cost - 389.92516412447964

Training step #16600, validation data: acc - 0.9165833333333333, cost - 394.4763250215415

Training step #16700, validation data: acc - 0.9165, cost - 388.58918296042964

Training step #16800, validation data: acc - 0.9196666666666666, cost - 384.7816449698689

Training step #16900, validation data: acc - 0.91725, cost - 391.359144878919

Training step #17000, validation data: acc - 0.9204166666666667, cost - 382.9705095635096

Training step #17100, validation data: acc - 0.9165833333333333, cost - 391.5820925457713

Training step #17200, validation data: acc - 0.9196666666666666, cost - 382.35479153544657

Training step #17300, validation data: acc - 0.9200833333333334, cost - 381.8306925860737

Training step #17400, validation data: acc - 0.9169166666666667, cost - 388.252949640559

Training step #17500, validation data: acc - 0.9201666666666667, cost - 377.6937686675494

Training step #17600, validation data: acc - 0.9194166666666667, cost - 376.59453964842737

Training step #17700, validation data: acc - 0.9218333333333333, cost - 374.19258954797624

Training step #17800, validation data: acc - 0.91975, cost - 380.4775527163632

Training step #17900, validation data: acc - 0.91875, cost - 379.24013471975525

Training step #18000, validation data: acc - 0.9196666666666666, cost - 377.2391360819021

Training step #18100, validation data: acc - 0.9188333333333333, cost - 384.9342321411932

Training step #18200, validation data: acc - 0.91775, cost - 377.077227654633

Training step #18300, validation data: acc - 0.9215, cost - 370.9759713740906

Training step #18400, validation data: acc - 0.9194166666666667, cost - 379.4007162183328

Training step #18500, validation data: acc - 0.92125, cost - 370.5573516891598

Training step #18600, validation data: acc - 0.9194166666666667, cost - 377.0938959725496

Training step #18700, validation data: acc - 0.9215, cost - 369.48926410474286

Training step #18800, validation data: acc - 0.922, cost - 368.095071918033

Training step #18900, validation data: acc - 0.92025, cost - 372.5312834803901

Training step #19000, validation data: acc - 0.9230833333333334, cost - 364.40938993774427

Training step #19100, validation data: acc - 0.9220833333333334, cost - 363.7180051888195

Training step #19200, validation data: acc - 0.9248333333333333, cost - 360.4171174961643

Training step #19300, validation data: acc - 0.9233333333333333, cost - 365.35834330067803

Training step #19400, validation data: acc - 0.9203333333333333, cost - 366.6088640299142

Training step #19500, validation data: acc - 0.921, cost - 366.03087082522677

Training step #19600, validation data: acc - 0.92125, cost - 368.40918911389434

Training step #19700, validation data: acc - 0.92075, cost - 363.7662556647339

Training step #19800, validation data: acc - 0.9236666666666666, cost - 357.614250014532

Training step #19900, validation data: acc - 0.9225, cost - 366.820138719616

Training step #20000, validation data: acc - 0.92325, cost - 358.4281277853614

Training step #20100, validation data: acc - 0.92125, cost - 363.5968204954794

Training step #20200, validation data: acc - 0.9226666666666666, cost - 358.31324739498814

Training step #20300, validation data: acc - 0.9235, cost - 356.4822576574201

Training step #20400, validation data: acc - 0.9213333333333333, cost - 361.15504805436547

Training step #20500, validation data: acc - 0.9258333333333333, cost - 353.1427055286014

Training step #20600, validation data: acc - 0.9229166666666667, cost - 353.19649949018964

Training step #20700, validation data: acc - 0.9255, cost - 349.7644948306569

Training step #20800, validation data: acc - 0.9246666666666666, cost - 352.75308436221417

Training step #20900, validation data: acc - 0.923, cost - 355.86967830383094

Training step #21000, validation data: acc - 0.9233333333333333, cost - 355.7168701588595

Training step #21100, validation data: acc - 0.9235, cost - 355.9693203356527

Training step #21200, validation data: acc - 0.9224166666666667, cost - 353.3393142666987

Training step #21300, validation data: acc - 0.9260833333333334, cost - 346.520341750742

Training step #21400, validation data: acc - 0.92375, cost - 355.36213129667334

Training step #21500, validation data: acc - 0.9259166666666667, cost - 345.9683956897312

Training step #21600, validation data: acc - 0.9235, cost - 352.80023580250025

Training step #21700, validation data: acc - 0.925, cost - 347.66096080447636

Training step #21800, validation data: acc - 0.92575, cost - 345.44023328764854

Training step #21900, validation data: acc - 0.9245, cost - 350.2750177931967

Training step #22000, validation data: acc - 0.9264166666666667, cost - 343.1949336169117

Training step #22100, validation data: acc - 0.9248333333333333, cost - 341.51333800393655

Training step #22200, validation data: acc - 0.9279166666666666, cost - 339.3331024403572

Training step #22300, validation data: acc - 0.9255833333333333, cost - 341.78029906273764

Training step #22400, validation data: acc - 0.9239166666666667, cost - 345.1880903611458

Training step #22500, validation data: acc - 0.9239166666666667, cost - 345.8750441915371

Training step #22600, validation data: acc - 0.9248333333333333, cost - 347.3174601328104

Training step #22700, validation data: acc - 0.9243333333333333, cost - 345.07908301339126

Training step #22800, validation data: acc - 0.9276666666666666, cost - 336.02796007343983

Training step #22900, validation data: acc - 0.925, cost - 346.90979709024634

Training step #23000, validation data: acc - 0.927, cost - 335.99363438532345

Training step #23100, validation data: acc - 0.9255, cost - 341.05525438714136

Training step #23200, validation data: acc - 0.9270833333333334, cost - 337.8897025493301

Running time: 33.698 sec