2. a

Regular Gradient Descent

Alpha: 0.00820 # of interations: 117 Cost: 11.70771
Alpha: 0.00810 # of interations: 118 Cost: 11.70900
Alpha: 0.00800 # of interations: 120 Cost: 11.70933
Alpha: 0.00790 # of interations: 122 Cost: 11.70968
Alpha: 0.00780 # of interations: 124 Cost: 11.71006
Alpha: 0.00770 # of interations: 126 Cost: 11.71047
Alpha: 0.00760 # of interations: 128 Cost: 11.71090
Alpha: 0.00750 # of interations: 130 Cost: 11.71136
Alpha: 0.00740 # of interations: 132 Cost: 11.71185
Alpha: 0.00730 # of interations: 134 Cost: 11.71237
Alpha: 0.00720 # of interations: 135 Cost: 11.71391
Alpha: 0.00710 # of interations: 137 Cost: 11.71450
Alpha: 0.00700 # of interations: 139 Cost: 11.71514
Alpha: 0.00690 # of interations: 142 Cost: 11.71484
Alpha: 0.00680 # of interations: 144 Cost: 11.71556
Alpha: 0.00670 # of interations: 146 Cost: 11.71632
Alpha: 0.00660 # of interations: 148 Cost: 11.71714
Alpha: 0.00650 # of interations: 150 Cost: 11.71800
Alpha: 0.00640 # of interations: 152 Cost: 11.71892
Alpha: 0.00630 # of interations: 154 Cost: 11.71990
Alpha: 0.00620 # of interations: 157 Cost: 11.71996
Alpha: 0.00610 # of interations: 159 Cost: 11.72106
Alpha: 0.00600 # of interations: 161 Cost: 11.72223
Alpha: 0.00590 # of interations: 164 Cost: 11.72249
Alpha: 0.00580 # of interations: 166 Cost: 11.72381
Alpha: 0.00570 # of interations: 169 Cost: 11.72422
Alpha: 0.00560 # of interations: 171 Cost: 11.72569
Alpha: 0.00550 # of interations: 174 Cost: 11.72628
Alpha: 0.00540 # of interations: 176 Cost: 11.72793
Alpha: 0.00530 # of interations: 179 Cost: 11.72870
Alpha: 0.00520 # of interations: 182 Cost: 11.72957
Alpha: 0.00510 # of interations: 185 Cost: 11.73055
Alpha: 0.00500 # of interations: 187 Cost: 11.73263
Alpha: 0.00490 # of interations: 190 Cost: 11.73384
Alpha: 0.00480 # of interations: 193 Cost: 11.73518
Alpha: 0.00470 # of interations: 197 Cost: 11.73567
Alpha: 0.00460 # of interations: 200 Cost: 11.73729
Alpha: 0.00450 # of interations: 203 Cost: 11.73906
Alpha: 0.00440 # of interations: 207 Cost: 11.74001
Alpha: 0.00430 # of interations: 210 Cost: 11.74212
Alpha: 0.00420 # of interations: 214 Cost: 11.74342
Alpha: 0.00410 # of interations: 218 Cost: 11.74492
Alpha: 0.00400 # of interations: 221 Cost: 11.74761
Alpha: 0.00390 # of interations: 225 Cost: 11.74954
Alpha: 0.00380 # of interations: 230 Cost: 11.75072

Alpha: 0.00370 # of interations: 234 Cost: 11.75315
Alpha: 0.00360 # of interations: 238 Cost: 11.75585
Alpha: 0.00350 # of interations: 243 Cost: 11.75785
Alpha: 0.00340 # of interations: 248 Cost: 11.76017
Alpha: 0.00330 # of interations: 253 Cost: 11.76284
Alpha: 0.00320 # of interations: 258 Cost: 11.76588
Alpha: 0.00310 # of interations: 264 Cost: 11.76833
Alpha: 0.00300 # of interations: 269 Cost: 11.77221
Alpha: 0.00290 # of interations: 275 Cost: 11.77557
Alpha: 0.00280 # of interations: 282 Cost: 11.77847
Alpha: 0.00270 # of interations: 288 Cost: 11.78292
Alpha: 0.00260 # of interations: 295 Cost: 11.78702
Alpha: 0.00250 # of interations: 303 Cost: 11.79081
Alpha: 0.00240 # of interations: 310 Cost: 11.79636
Alpha: 0.00230 # of interations: 318 Cost: 11.80177
Alpha: 0.00220 # of interations: 327 Cost: 11.80713
Alpha: 0.00210 # of interations: 336 Cost: 11.81355
Alpha: 0.00200 # of interations: 346 Cost: 11.82017
Alpha: 0.00190 # of interations: 357 Cost: 11.82715
Alpha: 0.00180 # of interations: 368 Cost: 11.83566
Alpha: 0.00170 # of interations: 380 Cost: 11.84495
Alpha: 0.00160 # of interations: 393 Cost: 11.85527
Alpha: 0.00150 # of interations: 407 Cost: 11.86695
Alpha: 0.00140 # of interations: 423 Cost: 11.87942
Alpha: 0.00130 # of interations: 439 Cost: 11.89517
Alpha: 0.00120 # of interations: 458 Cost: 11.91185
Alpha: 0.00110 # of interations: 478 Cost: 11.93231
Alpha: 0.00100 # of interations: 500 Cost: 11.95663
Alpha: 0.00090 # of interations: 524 Cost: 11.98628
Alpha: 0.00080 # of interations: 551 Cost: 12.02230
Alpha: 0.00070 # of interations: 580 Cost: 12.06852
Alpha: 0.00060 # of interations: 612 Cost: 12.12809
Alpha: 0.00050 # of interations: 643 Cost: 12.21122
Alpha: 0.00040 # of interations: 668 Cost: 12.33250
Alpha: 0.00030 # of interations: 665 Cost: 12.52812
Alpha: 0.00020 # of interations: 561 Cost: 12.88404
Alpha: 0.00010 # of interations: 501 Cost: 13.29143

Newton’s Method Gradient Descent

```
def log_hess(theta, x):
        g = logistic_func(theta,x)
        hess = 0
        for index in range(x.shape[0]-1):
                x_i = x[index,:]
                hess += x_i.T.dot(x_i.T)*g[index]*(1-g[index])
        return hess

def grad_desc(theta, x, y, tol, maxiter):
        nll_vec = []
        nll_vec.append(neg_log_like(theta, x, y))
        nll_delta = 2.0*tol
        iter = 0
        while(nll_delta > tol) and (iter < maxiter):
                alpha = 1/log_hess(theta, x)
                theta = theta -(alpha * log_grad(theta, x, y))
                nll_vec.append(neg_log_like(theta, x, y))
                nll_delta = nll_vec[-2] - nll_vec[-1]
                iter += 1
        return theta, np.array(nll_vec), iter, alpha
```

```
def grad_desc(theta, x, y, alpha, tol, maxiter):
        nll_vec = []
        data = np.c_[x,y]
        batch = int(floor(data.shape[0]/5))
        nll_vec.append(neg_log_like(theta, x[0:batch,:], y[0:batch]))
        nll_delta = 2.0*tol
        iter = 0
        while(abs(nll_delta) > tol) and (iter < maxiter):
        #while(condition) and (iter < maxiter):
                #if (iter%30 == 0) and (nll_delta < tol):
                        #condition = False
                data = np.random.permutation(data)
                theta = theta - (alpha * log_grad(theta, data[0:batch,:-1], data[0:batch,-1]))
                nll_vec.append(neg_log_like(theta, data[0:batch,:-1], data[0:batch,-1]))
                nll_delta = nll_vec[-2] - nll_vec[-1]
                iter += 1
        return theta, np.array(nll_vec), iter
```

Resulting Observation

```
Alpha: 0.00050  # of interations: 5739  Cost: 1.62177
Alpha: 0.00049  # of interations: 107  Cost: 2.06272
Alpha: 0.00048  # of interations: 2727  Cost: 1.58326
Alpha: 0.00047  # of interations: 444  Cost: 1.87826
Alpha: 0.00046  # of interations: 125  Cost: 2.20548
Alpha: 0.00045  # of interations: 1199  Cost: 5.75306
Alpha: 0.00044  # of interations: 7047  Cost: 2.18396
Alpha: 0.00043  # of interations: 2036  Cost: 1.76382
Alpha: 0.00042  # of interations: 1094  Cost: 1.27837
Alpha: 0.00041  # of interations: 7665  Cost: 1.46310
Alpha: 0.00040  # of interations: 24  Cost: 3.15681
Alpha: 0.00039  # of interations: 2698  Cost: 1.99101
Alpha: 0.00038  # of interations: 304  Cost: 2.66233
Alpha: 0.00037  # of interations: 3798  Cost: 1.26904
Alpha: 0.00036  # of interations: 1350  Cost: 1.50054
Alpha: 0.00035  # of interations: 173  Cost: 2.26908
Alpha: 0.00034  # of interations: 249  Cost: 1.33856
Alpha: 0.00033  # of interations: 597  Cost: 2.28638
Alpha: 0.00032  # of interations: 1896  Cost: 5.15034
Alpha: 0.00031  # of interations: 64  Cost: 2.29230
Alpha: 0.00030  # of interations: 2168  Cost: 2.40023
Alpha: 0.00029  # of interations: 367  Cost: 3.29665
Alpha: 0.00028  # of interations: 624  Cost: 1.04849
Alpha: 0.00027  # of interations: 1891  Cost: 5.76552
Alpha: 0.00026  # of interations: 1504  Cost: 1.11181
Alpha: 0.00025  # of interations: 1319  Cost: 2.21751
Alpha: 0.00024  # of interations: 3186  Cost: 0.63406
Alpha: 0.00023  # of interations: 7035  Cost: 2.01812
Alpha: 0.00022  # of interations: 473  Cost: 2.29497
```

Alpha: 0.00021 # of interations: 4593 Cost: 0.88849
Alpha: 0.00020 # of interations: 273 Cost: 2.73992
Alpha: 0.00019 # of interations: 3345 Cost: 0.97425
Alpha: 0.00018 # of interations: 40 Cost: 3.68858
Alpha: 0.00017 # of interations: 2858 Cost: 2.07787
Alpha: 0.00016 # of interations: 703 Cost: 1.80264
Alpha: 0.00015 # of interations: 172 Cost: 2.58985
Alpha: 0.00014 # of interations: 1416 Cost: 2.36337
Alpha: 0.00013 # of interations: 2352 Cost: 1.42008
Alpha: 0.00012 # of interations: 556 Cost: 3.97444
Alpha: 0.00011 # of interations: 543 Cost: 0.91435
Alpha: 0.00010 # of interations: 72 Cost: 4.57289
Alpha: 0.00009 # of interations: 3647 Cost: 1.63894
Alpha: 0.00008 # of interations: 4663 Cost: 0.91516
Alpha: 0.00007 # of interations: 2747 Cost: 1.92812
Alpha: 0.00006 # of interations: 1109 Cost: 1.91238
Alpha: 0.00005 # of interations: 2511 Cost: 1.01199
Alpha: 0.00004 # of interations: 4656 Cost: 1.27266
Alpha: 0.00003 # of interations: 3228 Cost: 1.68760
Alpha: 0.00002 # of interations: 59 Cost: 8.01102
Alpha: 0.00001 # of interations: 211 Cost: 6.76060