**Лабораторна робота № 8**

**ДОСЛІДЖЕННЯ МЕТОДІВ НЕКОНТРОЬОВАНОГО НАВЧАННЯ**

Тема: «Ресурси Keras. TensorFlow. Навчання лінійної регресії».

Мета: Дослідження ресурсу Keras і TensorFlow. Застосування TensorFlow.

Час виконання: 4 години.

Навчальні питання: 1). Структура і ресурси Keras і TensorFlow;

**Завдання: Використовуючи засоби TensorFlow, реалізувати код наведений нижче та дослідити структуру розрахункового алгоритму.**

Лістинг:

linear\_regression\_keras.py:

import tensorflow as tf

import numpy as np

*class* KerasLinearRegression:

*def* \_\_init\_\_(*self*, *learning\_rate*=0.001, *epochs*=20000, *batch\_size*=100):

*self*.model = tf.keras.Sequential([

tf.keras.layers.Dense(1, *input\_dim*=1, *use\_bias*=True,

*kernel\_initializer*='random\_normal', *bias\_initializer*='zeros')

])

*self*.model.compile(*optimizer*=tf.optimizers.SGD(*learning\_rate*=*learning\_rate*), *loss*='mean\_squared\_error')

*self*.epochs = *epochs*

*self*.batch\_size = *batch\_size*

*def* train(*self*, *X\_data*, *y\_data*):

*self*.model.fit(*X\_data*, *y\_data*, *epochs*=*self*.epochs, *batch\_size*=*self*.batch\_size, *verbose*=100)

*def* get\_parameters(*self*):

return *self*.model.weights[0].numpy()[0][0], *self*.model.weights[1].numpy()

*def* generate\_data(*n\_samples*):

X\_data = np.random.uniform(0, 1, (*n\_samples*, 1)).astype(np.float32)

y\_data = 2 \* X\_data + 1 + np.random.normal(0, 0.2, (*n\_samples*, 1)).astype(np.float32)

return X\_data, y\_data

linear\_regression.py:

import tensorflow as tf

import numpy as np

*class* LinearRegression:

*def* \_\_init\_\_(*self*, *learning\_rate*=0.001, *stddev*=0.01):

*self*.k = tf.Variable(tf.random.normal((1, 1), *stddev*=*stddev*, *dtype*=tf.float32), *name*='slope')

*self*.b = tf.Variable(tf.zeros((1,), *dtype*=tf.float32), *name*='bias')

*self*.optimizer = tf.optimizers.SGD(*learning\_rate*=*learning\_rate*)

*def* model(*self*, *X*):

return tf.matmul(*X*, *self*.k) + *self*.b

*def* loss\_fn(*self*, *y\_true*, *y\_pred*):

return tf.reduce\_sum(tf.square(*y\_true* - *y\_pred*))

*def* train(*self*, *X\_data*, *y\_data*, *n\_samples*, *batch\_size*, *num\_steps*):

for step in range(*num\_steps*):

indices = np.random.choice(*n\_samples*, *batch\_size*)

X\_batch, y\_batch = *X\_data*[indices], *y\_data*[indices]

with tf.GradientTape() as tape:

y\_pred = *self*.model(X\_batch)

loss = *self*.loss\_fn(y\_batch, y\_pred)

gradients = tape.gradient(loss, [*self*.k, *self*.b])

*self*.optimizer.apply\_gradients(zip(gradients, [*self*.k, *self*.b]))

if (step + 1) % 100 == 0:

print(*f*"Step {step + 1}: loss = {loss.numpy()}, k = {*self*.k.numpy()[0][0]}, b = {*self*.b.numpy()[0]}")

Main:

import numpy as np

from linear\_regression import LinearRegression

from linear\_regression\_keras import KerasLinearRegression, generate\_data

*def* train\_with\_tensorflow():

n\_samples, batch\_size, num\_steps = 1000, 100, 20000

X\_data = np.random.uniform(0, 1, (n\_samples, 1)).astype(np.float32)

y\_data = 2 \* X\_data + 1 + np.random.normal(0, 0.2, (n\_samples, 1)).astype(np.float32)

lr\_model = LinearRegression()

lr\_model.train(X\_data, y\_data, n\_samples, batch\_size, num\_steps)

*def* train\_with\_keras():

# Keras approach

n\_samples = 1000

X\_data, y\_data = generate\_data(n\_samples)

lr\_model = KerasLinearRegression()

lr\_model.train(X\_data, y\_data)

k, b = lr\_model.get\_parameters()

print(*f*"Final parameters: k = {k}, b = {b}")

*def* main():

print("Select the training method:")

print("1. TensorFlow 1.x style")

print("2. Keras style")

choice = input("Enter 1 or 2: ").strip()

if choice == '1':

train\_with\_tensorflow()

elif choice == '2':

train\_with\_keras()

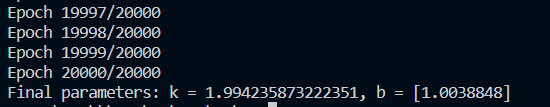
else:

print("Invalid choice! Please enter 1 or 2.")

if \_\_name\_\_ == '\_\_main\_\_':

main()

Метод 2:



Метод 1:

Select the training method:

1. TensorFlow 1.x style

2. Keras style

Enter 1 or 2: 1

Step 100: loss = 3.9606356620788574, k = 1.7191243171691895, b = 1.1463872194290161

Step 200: loss = 4.056914806365967, k = 1.941674828529358, b = 1.0388073921203613

Step 300: loss = 3.8510093688964844, k = 1.995446801185608, b = 1.0060477256774902

Step 400: loss = 4.058037757873535, k = 2.010113477706909, b = 1.0049608945846558

Step 500: loss = 3.830792188644409, k = 2.01107120513916, b = 0.999864399433136

Step 600: loss = 3.9139301776885986, k = 2.034122943878174, b = 1.0033162832260132

Step 700: loss = 4.03654146194458, k = 2.0196869373321533, b = 0.9904381036758423

Step 800: loss = 3.599066734313965, k = 2.012033224105835, b = 0.9918174147605896

Step 900: loss = 4.184928894042969, k = 2.011739492416382, b = 0.9994075298309326

Step 1000: loss = 3.648001194000244, k = 2.0187718868255615, b = 0.9907473921775818

Step 1100: loss = 4.167655944824219, k = 2.0179498195648193, b = 0.9856786727905273

Step 1200: loss = 3.656017541885376, k = 2.0130882263183594, b = 0.9872466921806335

Step 1300: loss = 4.369283676147461, k = 2.0214295387268066, b = 0.9832496047019958

Step 1400: loss = 4.163578033447266, k = 2.019727945327759, b = 1.0017242431640625

Step 1500: loss = 3.8904876708984375, k = 2.014974355697632, b = 0.9964690208435059

Step 1600: loss = 3.7443084716796875, k = 1.9957807064056396, b = 0.9822306036949158

Step 1700: loss = 3.844856023788452, k = 2.008066415786743, b = 0.9843012094497681

Step 1800: loss = 3.890533924102783, k = 2.005155086517334, b = 0.9944863319396973

Step 1900: loss = 3.6175668239593506, k = 2.004701614379883, b = 0.9879655838012695

Step 2000: loss = 4.723674774169922, k = 2.0243499279022217, b = 0.9880208969116211

Step 2100: loss = 3.868990421295166, k = 2.022804021835327, b = 0.9935722351074219

Step 2200: loss = 3.491848945617676, k = 2.0166337490081787, b = 0.995495617389679

Step 2300: loss = 3.5022079944610596, k = 2.02649188041687, b = 0.9966190457344055

Step 2400: loss = 4.945681571960449, k = 2.017584800720215, b = 0.9956493973731995

Step 2500: loss = 3.5721638202667236, k = 2.0092813968658447, b = 0.9921051859855652

Step 2600: loss = 4.786834716796875, k = 2.013857126235962, b = 0.9823480844497681

Step 2700: loss = 3.940120220184326, k = 2.0141305923461914, b = 0.9891675114631653

Step 2800: loss = 3.1349329948425293, k = 2.015599489212036, b = 0.9906845688819885

Step 2900: loss = 3.921722173690796, k = 2.0158190727233887, b = 0.9948129653930664

Step 3000: loss = 3.6820785999298096, k = 2.0174872875213623, b = 0.9973914623260498

Step 3100: loss = 4.116954326629639, k = 2.014457941055298, b = 0.9954873323440552

Step 3200: loss = 3.3831751346588135, k = 2.0064666271209717, b = 0.9858608841896057

Step 3300: loss = 3.191936492919922, k = 2.0159029960632324, b = 0.9949936866760254

Step 3400: loss = 4.348914623260498, k = 2.0059444904327393, b = 0.9905765056610107

Step 3500: loss = 3.354916572570801, k = 2.0099527835845947, b = 0.9978501200675964

Step 3600: loss = 3.531585216522217, k = 2.026015281677246, b = 0.9901974201202393

Step 3700: loss = 4.265809535980225, k = 2.0291004180908203, b = 0.9957201480865479

Step 3800: loss = 3.24320125579834, k = 2.0185372829437256, b = 0.9840766191482544

Step 3900: loss = 3.9811818599700928, k = 2.0218629837036133, b = 0.9888077974319458

Step 4000: loss = 4.059884071350098, k = 2.0236597061157227, b = 0.9891902208328247

Step 4100: loss = 3.291309356689453, k = 2.0165817737579346, b = 1.0021605491638184

Step 4200: loss = 3.5851335525512695, k = 2.007661819458008, b = 0.9801738858222961

Step 4300: loss = 4.268137454986572, k = 2.010225534439087, b = 0.9901493787765503

Step 4400: loss = 4.486814498901367, k = 2.01216459274292, b = 1.004342794418335

Step 4500: loss = 4.250624656677246, k = 2.0106911659240723, b = 0.9841013550758362

Step 4600: loss = 4.00250244140625, k = 2.0207231044769287, b = 0.9973956346511841

Step 4700: loss = 3.9813318252563477, k = 2.007662773132324, b = 0.9848219752311707

Step 4800: loss = 4.315022945404053, k = 2.0166401863098145, b = 0.9897185564041138

Step 4900: loss = 4.007515907287598, k = 2.018303394317627, b = 0.9979540705680847

Step 5000: loss = 3.6041383743286133, k = 2.0183513164520264, b = 0.9952415227890015

Step 5100: loss = 4.406717300415039, k = 2.0172929763793945, b = 1.0022140741348267

Step 5200: loss = 3.464690923690796, k = 2.0155816078186035, b = 0.9903892278671265

Step 5300: loss = 3.2527272701263428, k = 2.0190374851226807, b = 0.9911498427391052

Step 5400: loss = 2.9996337890625, k = 2.018397569656372, b = 0.9891429543495178

Step 5500: loss = 3.0559492111206055, k = 2.017585515975952, b = 0.9842830300331116

Step 5600: loss = 4.453238487243652, k = 2.022552251815796, b = 0.9971776008605957

Step 5700: loss = 4.752528190612793, k = 2.0243980884552, b = 0.9936736822128296

Step 5800: loss = 4.34019136428833, k = 2.0181875228881836, b = 0.9950118064880371

Step 5900: loss = 3.7302088737487793, k = 2.0150489807128906, b = 0.9838562607765198

Step 6000: loss = 3.8958215713500977, k = 2.0128941535949707, b = 0.9849376678466797

Step 6100: loss = 4.3375630378723145, k = 2.0249240398406982, b = 0.9916387796401978

Step 6200: loss = 3.3567447662353516, k = 2.0180885791778564, b = 0.9928038716316223

Step 6300: loss = 3.9351348876953125, k = 2.010026216506958, b = 0.9843723773956299

Step 6400: loss = 3.3840346336364746, k = 2.0172879695892334, b = 0.9972629547119141

Step 6500: loss = 4.264043807983398, k = 2.023181676864624, b = 0.9994959235191345

Step 6600: loss = 3.90689754486084, k = 2.011075019836426, b = 0.9913256168365479

Step 6700: loss = 4.127026557922363, k = 2.0236752033233643, b = 1.0031495094299316

Step 6800: loss = 4.216583251953125, k = 2.0115513801574707, b = 0.987281322479248

Step 6900: loss = 4.050770282745361, k = 2.013014078140259, b = 0.9903876781463623

Step 7000: loss = 3.824094295501709, k = 2.0110912322998047, b = 0.999465823173523

Step 7100: loss = 4.454554557800293, k = 2.0062906742095947, b = 0.9914597272872925

Step 7200: loss = 4.126769065856934, k = 2.0165562629699707, b = 0.9896445274353027

Step 7300: loss = 4.079434394836426, k = 2.016145706176758, b = 0.9895985722541809

Step 7400: loss = 4.177213668823242, k = 2.0170981884002686, b = 0.9940666556358337

Step 7500: loss = 3.8579494953155518, k = 2.0034778118133545, b = 0.9915633201599121

Step 7600: loss = 3.937614917755127, k = 2.0137853622436523, b = 0.988368034362793

Step 7700: loss = 3.2822413444519043, k = 2.0109570026397705, b = 0.9914796352386475

Step 7800: loss = 2.987626791000366, k = 2.0166831016540527, b = 0.9924240112304688

Step 7900: loss = 3.5209898948669434, k = 2.023399829864502, b = 0.9834612607955933

Step 8000: loss = 4.123538017272949, k = 2.0093753337860107, b = 0.998495876789093

Step 8100: loss = 3.539855480194092, k = 1.9982764720916748, b = 0.9918020963668823

Step 8200: loss = 3.5555295944213867, k = 2.008409261703491, b = 0.9876620173454285

Step 8300: loss = 3.870143175125122, k = 2.0135090351104736, b = 0.9948394894599915

Step 8400: loss = 4.386763572692871, k = 2.013899087905884, b = 0.984706699848175

Step 8500: loss = 4.701160907745361, k = 2.0207178592681885, b = 0.994652509689331

Step 8600: loss = 4.072734355926514, k = 2.0169007778167725, b = 1.0088101625442505

Step 8700: loss = 3.755645990371704, k = 2.003652811050415, b = 0.9997513890266418

Step 8800: loss = 4.303529262542725, k = 2.0163676738739014, b = 0.9995673298835754

Step 8900: loss = 3.8822813034057617, k = 2.0146102905273438, b = 0.9789168238639832

Step 9000: loss = 4.527461051940918, k = 2.0063929557800293, b = 0.9915114641189575

Step 9100: loss = 3.445786952972412, k = 2.0221400260925293, b = 0.9922941327095032

Step 9200: loss = 3.857282876968384, k = 2.0147037506103516, b = 0.989638090133667

Step 9300: loss = 3.617755651473999, k = 2.0181009769439697, b = 0.976966142654419

Step 9400: loss = 4.131197929382324, k = 2.0132856369018555, b = 0.9905235171318054

Step 9500: loss = 3.7629895210266113, k = 2.0141820907592773, b = 0.9732521772384644

Step 9600: loss = 3.908447742462158, k = 2.0183823108673096, b = 1.0035014152526855

Step 9700: loss = 4.283646106719971, k = 2.0155527591705322, b = 0.9886672496795654

Step 9800: loss = 5.097985744476318, k = 2.010366201400757, b = 0.9893507957458496

Step 9900: loss = 3.091855049133301, k = 2.008700132369995, b = 0.9846041202545166

Step 10000: loss = 4.1607255935668945, k = 2.0023105144500732, b = 0.9950421452522278

Step 10100: loss = 3.75822114944458, k = 2.007474184036255, b = 0.998035728931427

Step 10200: loss = 3.332136392593384, k = 2.011624336242676, b = 0.9939953684806824

Step 10300: loss = 3.7074639797210693, k = 2.0186080932617188, b = 0.9937260746955872

Step 10400: loss = 3.9509634971618652, k = 2.006563186645508, b = 0.9845948815345764

Step 10500: loss = 4.568153381347656, k = 2.0196776390075684, b = 1.0003719329833984

Step 10600: loss = 4.113345146179199, k = 2.015347719192505, b = 0.9981318116188049

Step 10700: loss = 2.579376697540283, k = 2.0138120651245117, b = 0.9790875911712646

Step 10800: loss = 3.93056058883667, k = 2.0181713104248047, b = 0.9928462505340576

Step 10900: loss = 4.638366222381592, k = 2.0147476196289062, b = 0.995055615901947

Step 11000: loss = 4.171931266784668, k = 2.016587018966675, b = 0.992033839225769

Step 11100: loss = 3.1258561611175537, k = 2.012852191925049, b = 0.9946041107177734

Step 11200: loss = 3.1338798999786377, k = 2.0133233070373535, b = 0.9903782606124878

Step 11300: loss = 4.422691822052002, k = 2.0138649940490723, b = 0.9898473024368286

Step 11400: loss = 4.172185897827148, k = 2.013185501098633, b = 0.9934626221656799

Step 11500: loss = 3.8825559616088867, k = 2.01724910736084, b = 0.9904443025588989

Step 11600: loss = 4.040125846862793, k = 2.018568992614746, b = 0.9908726811408997

Step 11700: loss = 3.9042248725891113, k = 2.0251317024230957, b = 0.9924067258834839

Step 11800: loss = 3.5733728408813477, k = 2.0122852325439453, b = 0.9893887042999268

Step 11900: loss = 3.5605967044830322, k = 2.010965585708618, b = 0.9951484203338623

Step 12000: loss = 3.120995283126831, k = 2.011643409729004, b = 1.0065513849258423

Step 12100: loss = 4.226470470428467, k = 2.012960433959961, b = 1.0019041299819946

Step 12200: loss = 4.033504486083984, k = 2.016071319580078, b = 0.9860190153121948

Step 12300: loss = 3.4181723594665527, k = 2.0250868797302246, b = 1.0007028579711914

Step 12400: loss = 4.4542059898376465, k = 2.0157358646392822, b = 0.9901561737060547

Step 12500: loss = 2.9690845012664795, k = 2.020745038986206, b = 0.9830555319786072

Step 12600: loss = 4.581418037414551, k = 2.0238261222839355, b = 0.9889572858810425

Step 12700: loss = 3.9700207710266113, k = 2.015946388244629, b = 1.0021125078201294

Step 12800: loss = 3.3862056732177734, k = 2.0112850666046143, b = 0.9906189441680908

Step 12900: loss = 4.505714416503906, k = 2.0303924083709717, b = 1.0045535564422607

Step 13000: loss = 3.7265703678131104, k = 2.0219643115997314, b = 0.9919236898422241

Step 13100: loss = 3.298264503479004, k = 2.0152742862701416, b = 0.9942460060119629

Step 13200: loss = 3.3049538135528564, k = 2.0135579109191895, b = 0.9921684265136719

Step 13300: loss = 3.69970965385437, k = 2.0077712535858154, b = 0.9935130476951599

Step 13400: loss = 4.029498100280762, k = 2.020737886428833, b = 1.011699914932251

Step 13500: loss = 4.07065486907959, k = 2.0151913166046143, b = 0.9903762340545654

Step 13600: loss = 3.7489750385284424, k = 2.0114641189575195, b = 0.9969268441200256

Step 13700: loss = 3.9514412879943848, k = 2.023674249649048, b = 0.9855378866195679

Step 13800: loss = 4.686232566833496, k = 2.020876169204712, b = 0.9897944331169128

Step 13900: loss = 4.594258785247803, k = 2.0018842220306396, b = 0.9888460040092468

Step 14000: loss = 3.2536849975585938, k = 2.0121684074401855, b = 0.9998080730438232

Step 14100: loss = 4.711583614349365, k = 2.009453773498535, b = 0.9848154187202454

Step 14200: loss = 3.41809344291687, k = 2.023430585861206, b = 0.9918920993804932

Step 14300: loss = 3.419558525085449, k = 2.020249128341675, b = 0.9920685887336731

Step 14400: loss = 3.670337200164795, k = 2.0141470432281494, b = 0.9896878004074097

Step 14500: loss = 3.5692052841186523, k = 2.0110678672790527, b = 1.0028679370880127

Step 14600: loss = 3.7315492630004883, k = 2.020369529724121, b = 0.9984058141708374

Step 14700: loss = 4.676361083984375, k = 2.0230519771575928, b = 0.9923545718193054

Step 14800: loss = 4.305851936340332, k = 2.0178937911987305, b = 0.9856052994728088

Step 14900: loss = 2.869866371154785, k = 2.014256715774536, b = 0.9863728880882263

Step 15000: loss = 3.639120101928711, k = 2.0130412578582764, b = 0.9920855760574341

Step 15100: loss = 3.5753908157348633, k = 2.0152533054351807, b = 0.9923590421676636

Step 15200: loss = 4.362462520599365, k = 2.012237071990967, b = 0.9793393015861511

Step 15300: loss = 3.322192668914795, k = 2.020282506942749, b = 0.9843166470527649

Step 15400: loss = 4.73637056350708, k = 2.0101358890533447, b = 0.9998275637626648

Step 15500: loss = 4.542746543884277, k = 2.018470525741577, b = 0.9997187852859497

Step 15600: loss = 3.787409782409668, k = 2.013502359390259, b = 0.9968921542167664

Step 15700: loss = 3.5836377143859863, k = 2.0012550354003906, b = 0.9844313859939575

Step 15800: loss = 4.1763763427734375, k = 2.014265537261963, b = 1.004096269607544

Step 15900: loss = 4.239386558532715, k = 2.021569013595581, b = 1.0049692392349243

Step 16000: loss = 4.412310600280762, k = 2.0190117359161377, b = 0.9940605759620667

Step 16100: loss = 4.484811305999756, k = 2.0123519897460938, b = 0.9893134236335754

Step 16200: loss = 5.377472400665283, k = 2.0035552978515625, b = 0.9977511167526245

Step 16300: loss = 3.9486942291259766, k = 2.0139336585998535, b = 0.9879185557365417

Step 16400: loss = 3.9690566062927246, k = 2.019559621810913, b = 0.9947648644447327

Step 16500: loss = 4.251282215118408, k = 2.021268606185913, b = 0.9917077422142029

Step 16600: loss = 3.4277777671813965, k = 2.0283777713775635, b = 1.0020699501037598

Step 16700: loss = 3.415165901184082, k = 2.0170083045959473, b = 0.987821638584137

Step 16800: loss = 3.7877185344696045, k = 2.002720594406128, b = 0.9938551783561707

Step 16900: loss = 3.1960513591766357, k = 2.0045361518859863, b = 0.9963074922561646

Step 17000: loss = 3.6389732360839844, k = 2.0124411582946777, b = 0.9899038076400757

Step 17100: loss = 4.288037300109863, k = 2.009796380996704, b = 0.9885345697402954

Step 17200: loss = 3.1923975944519043, k = 2.0233304500579834, b = 0.9889861941337585

Step 17300: loss = 5.051958084106445, k = 2.0261003971099854, b = 0.9949368238449097

Step 17400: loss = 4.308907508850098, k = 2.014266014099121, b = 0.9782708883285522

Step 17500: loss = 3.850036144256592, k = 2.0150020122528076, b = 1.0001294612884521

Step 17600: loss = 3.5274319648742676, k = 2.0226547718048096, b = 0.9952625036239624

Step 17700: loss = 4.031999111175537, k = 2.0151193141937256, b = 0.9865304231643677

Step 17800: loss = 4.350068092346191, k = 2.0115954875946045, b = 0.9935876727104187

Step 17900: loss = 3.212005615234375, k = 2.0097720623016357, b = 0.9941250085830688

Step 18000: loss = 3.2832326889038086, k = 2.011284112930298, b = 0.9975765347480774

Step 18100: loss = 3.4697537422180176, k = 2.009272575378418, b = 0.9861034750938416

Step 18200: loss = 4.041123390197754, k = 2.0079851150512695, b = 0.9874556064605713

Step 18300: loss = 3.909992218017578, k = 2.034041166305542, b = 1.0025849342346191

Step 18400: loss = 4.191422939300537, k = 2.016216516494751, b = 0.990290641784668

Step 18500: loss = 3.551609992980957, k = 2.010938882827759, b = 0.9895628094673157

Step 18600: loss = 3.282029151916504, k = 2.029557466506958, b = 0.9855635762214661

Step 18700: loss = 4.0716657638549805, k = 2.0247268676757812, b = 0.9873386025428772

Step 18800: loss = 3.436764717102051, k = 2.0145585536956787, b = 0.9925239086151123

Step 18900: loss = 4.666301727294922, k = 2.0024161338806152, b = 0.9900315403938293

Step 19000: loss = 3.0690035820007324, k = 2.021746873855591, b = 0.9869207739830017

Step 19100: loss = 3.7828116416931152, k = 2.010399103164673, b = 0.9903230667114258

Step 19200: loss = 4.929879665374756, k = 2.0295822620391846, b = 0.995797336101532

Step 19300: loss = 3.9446165561676025, k = 2.027927875518799, b = 0.9847323298454285

Step 19400: loss = 3.763227939605713, k = 2.028873920440674, b = 0.9927812218666077

Step 19500: loss = 4.449396133422852, k = 2.018902063369751, b = 0.9950982928276062

Step 19600: loss = 4.769429683685303, k = 2.02264404296875, b = 0.993626058101654

Step 19700: loss = 3.6859240531921387, k = 2.017360210418701, b = 0.9852877855300903

Step 19800: loss = 3.278519630432129, k = 2.013645887374878, b = 0.9919198155403137

Step 19900: loss = 4.075407981872559, k = 2.0186095237731934, b = 1.0030368566513062

Step 20000: loss = 3.759477376937866, k = 2.0140769481658936, b = 0.9906364679336548

<https://github.com/PavlenkoOks/AI>