

## Лабораторна робота № 8

### ДОСЛІДЖЕННЯ МЕТОДІВ НЕКОНТРОБОВАНОГО 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_r
ate), 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:

```
Epoch 19997/20000
Epoch 19998/20000
Epoch 19999/20000
Epoch 20000/20000
Final parameters: k = 1.994235873222351, b = [1.0038848]
```

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>