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Project3-Algorithms

Problem2:

- Test dataset:

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welcome to algorithm project3: k-means!!!!  
if you want to run k-means on the test case,please input1:  
if you want to run k-means on the power consumption dataset,please input2:  
you can also input any other numbers to quit,thanks:)  
  
1  
this is the time of 1:  
  
the coordinate of class 1 is [-1.33185677 -1.18008685],  
  
the coordinate of class 2 is [-4.25286253  6.56930857],  
  
the number of each class: Counter({0: 106, 1: 94})  
the loss: 134.38987139100917  
this is the time of 2:  
  
the coordinate of class 1 is [3.673693522502052,  0.5042906226986886],  
  
the coordinate of class 2 is [6.738546428426376,  10.033809958607627],  
  
the number of each class: Counter({0: 102, 1: 98})  
the loss: 43.288364602277824  
this is the time of 3:  
  
the coordinate of class 1 is [0.28154898078587665, -0.04052214517180402],  
  
the coordinate of class 2 is [10.144049812419768,  10.211900009415324],  
  
the number of each class: Counter({0: 100, 1: 100})  
the loss: 31.00297214358635
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this is the time of 4:  
  
the coordinate of class 1 is [0.06026253328707723, -0.08038639294559319],  
  
the coordinate of class 2 is [10.168086243285888, 10.046715814097372],  
  
the number of each class: Counter({0: 100, 1: 100})  
the loss: 30.96376193434194  
this is the time of 5:  
  
the coordinate of class 1 is [0.06026253328707723, -0.08038639294559319],  
  
the coordinate of class 2 is [10.168086243285888, 10.046715814097372],  
  
the number of each class: Counter({0: 100, 1: 100})  
the loss: 30.96376193434194  
Since the value of loss has no further changes at the 5 time, loop out!!!
```

In each iteration, the coordinates of each centroid, the count of the number of points assigned to each centroid and the losses are printed out as the figure above.

Besides, at the time 6, the value of loss function will not change, and the iteration loop ends.

- Power dataset:
k=2:

```
this is the time of 1:

the coordinate of class 1 is [ 0.574  0.056 242.11   2.8    0.     0.     0.    ],
the coordinate of class 2 is [ 0.17   0.   243.22   0.6   0.     0.     0.    ],
the number of each class: Counter({0: 1539590, 1: 509698})
the loss: 222.99250103306196
this is the time of 2:

the coordinate of class 1 is [1.354098912048014, 0.13798531427196295, 239.78829894972185, 5.734064783480213, 1.490010327424834, 1.6414448002390247, 8.470408355471262],
the coordinate of class 2 is [0.2987457434912118, 0.0806074123486804, 244.01623922384238, 1.2860087504168178, 0.010064941434989896, 0.26266750377680553, 0.381037493378328],
the number of each class: Counter({1: 1245756, 0: 803524})
the loss: 130.841002484862
this is the time of 3:

the coordinate of class 1 is [2.0702388155175724, 0.14295510526134025, 239.35460766575176, 8.496390898093645, 2.8090797536850176, 2.7180034448255435, 15.89294159228598],
the coordinate of class 2 is [0.4603937592913728, 0.11130409486291255, 241.7978579914893, 2.003454769635286, 0.033691991048006194, 0.3829401584258876, 0.3731123911905702],
the number of each class: Counter({1: 1308800, 0: 740480})

this is the time of 4:

the coordinate of class 1 is [2.0788025415945746, 0.1401001377484988, 239.48644824980684, 8.71145068063962, 2.9578705704407953, 2.501715103716508, 17.150487521607605],
the coordinate of class 2 is [0.5330937927871044, 0.11444395782397963, 241.60557682613293, 2.3173285452341505, 0.08319911369193154, 0.6177880561222494, 0.4092099633251834],
the number of each class: Counter({1: 1320673, 0: 728607})
the loss: 95.70737941368327
this is the time of 5:

the coordinate of class 1 is [2.06845944384275, 0.13959449744513644, 239.4976306294292, 8.66643032526431, 2.8101610333142557, 2.2261438608193442, 17.407528338322305],
the coordinate of class 2 is [0.5526961117549848, 0.11495356837007836, 241.58035637136567, 2.399649875481982, 0.19053315998737008, 0.786755691984314, 0.4179081422880607],
the number of each class: Counter({1: 1326689, 0: 722591})
the loss: 95.5720375262462
this is the time of 6:

the coordinate of class 1 is [2.060299740793824, 0.13919675999287118, 239.50825836471344, 8.631673796102765, 2.596870151994697, 2.175038161283492, 17.54754764451813],
the coordinate of class 2 is [0.5640137304219633, 0.1152819357061185, 241.5651235745823, 2.4469976007958096, 0.31858257662496636, 0.821117835453238, 0.4186866703500218],
the number of each class: Counter({1: 1331069, 0: 718211})
the loss: 95.50055683933573

this is the time of 7:

the coordinate of class 1 is [2.0533475065126474, 0.13878055334714787, 239.51795975001377, 8.602080725580311, 2.397580933736743, 2.1738723021507607, 17.650882540089192],
the coordinate of class 2 is [0.5726886404836562, 0.11558520407282517, 241.5531206571868, 2.4833164922344984, 0.4336108796764105, 0.8262020977124401, 0.4192938157225508],
the number of each class: Counter({1: 1333667, 0: 715613})
the loss: 95.45492479456163
this is the time of 8:

the coordinate of class 1 is [2.047539823899162, 0.13848183585263085, 239.52531945341659, 8.577340545797414, 2.2743675701810897, 2.176043476012873, 17.71289370092494],
the coordinate of class 2 is [0.578689242517022, 0.11579067338399276, 241.54520710195305, 2.5085108951499957, 0.583549986158494, 0.8276623774900331, 0.4195874982285683],
the number of each class: Counter({1: 1334861, 0: 714419})
the loss: 95.4391557175338
this is the time of 9:

the coordinate of class 1 is [2.0443074498297986, 0.13833417084373187, 239.52955482709447, 8.563548001942477, 2.2180919040807043, 2.1747405934052706, 17.741571822697885],
the coordinate of class 2 is [0.5817330628432118, 0.11589000053189623, 241.5411335862239, 2.5213210963552286, 0.5352527341798134, 0.8295657750132786, 0.4197073702805011],
the number of each class: Counter({1: 1335330, 0: 713950})
the loss: 95.4359981236813
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this is the time of 10:

the coordinate of class 1 is [2.042970740247853, 0.13825865116605887, 239.5320837593921, 8.557762308284543, 2.195653757265915, 2.1743315358218362, 17.752870649205125],  

the coordinate of class 2 is [0.5829614417409583, 0.11593826095422678, 241.5390749477962, 2.526536613509577, 0.5478406086884889, 0.8302569402320026, 0.4197501741142639],  

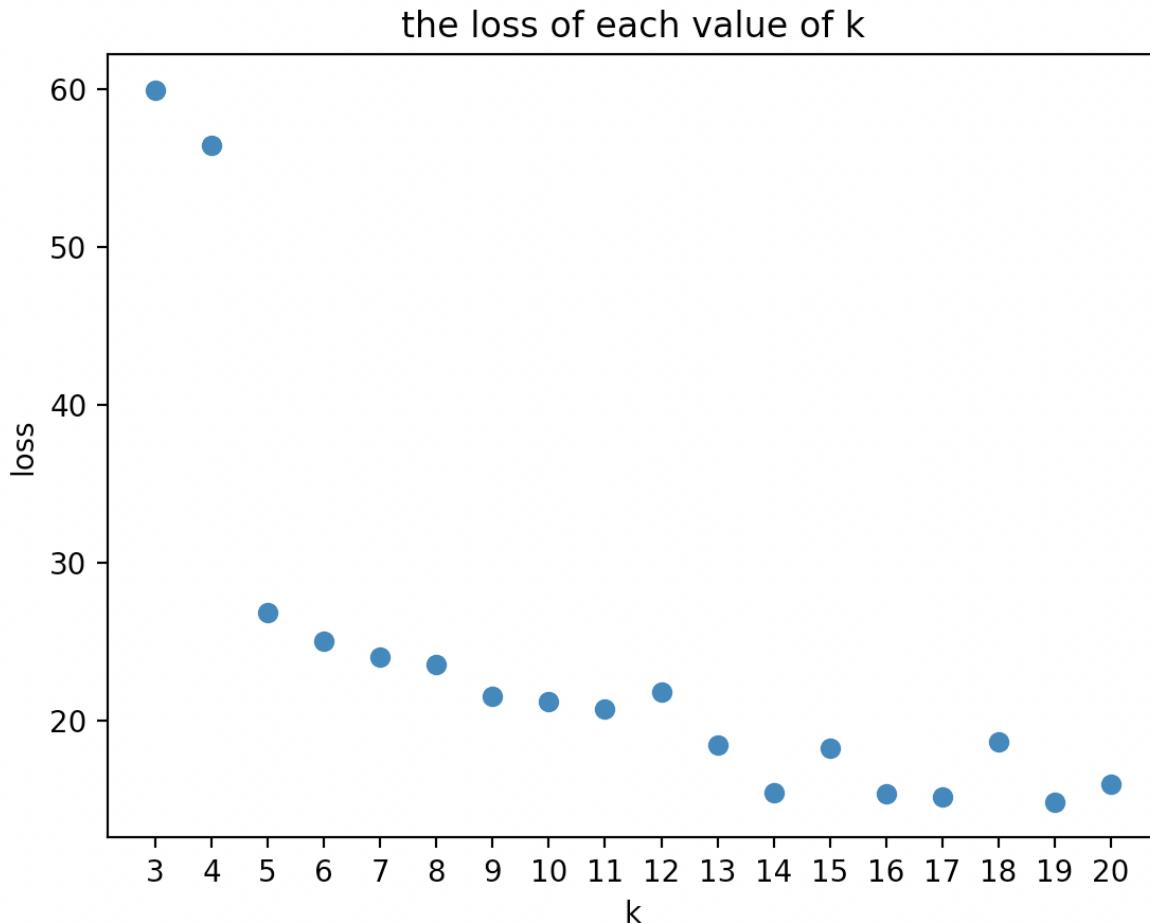
the number of each class: Counter({1: 1335514, 0: 713766})  

the loss: 95.43549802914207

```

k=3-20

- A scatter plot containing the loss of the last iteration of training for each value of K;
- using the elbow method (see Resources) find the value of K which best fits the data



By using the elbow method, we can find that when the value of k is 5, the value of loss decreases dramatically as k changes from 4 to 5; when k is larger than 5, as the increasement of k, the decreasement of loss is a little bit slow. Therefore, we can conclude that K=5 best fits the data!

- The coordinates of each centroid for each value of K ;
and the number of points assigned to each centroid for each value of K,

k=3:

```

k=3!!!!
this is the time of 1:

the coordinate of class 1 is [  0.254   0.054 242.49   1.     0.     0.     1.    ],
the coordinate of class 2 is [  1.818   0.37  243.48   7.6    2.     0.    18.    ],
the coordinate of class 3 is [  1.856   0.28  241.63   7.6    0.     0.     1.    ],

the number of each class: Counter({0: 1136609, 1: 708673, 2: 203998})
the loss: 100.13833019372839
this is the time of 2:
|
the coordinate of class 1 is [0.3591409482063789, 0.1081310934543264, 241.86598758241504, 1.5848239808059927, 0.021792014668192843, 0.36808084398416696, 0.4227487200963568],
the coordinate of class 2 is [2.023370234226439, 0.1374852858793932, 239.56414271464607, 8.472928514820794, 2.039761639806989, 1.9893646293847798, 17.873294170936383],
the coordinate of class 3 is [1.93587277326248, 0.16270119314895423, 239.55433955234813, 8.224195335248137, 4.062998813635428, 4.082677281149815, 0.4330728732634634],
the number of each class: Counter({0: 1224783, 1: 707029, 2: 117468})
the loss: 87.57591473175025

this is the time of 8:

the coordinate of class 1 is [0.5238854009429468, 0.11419035912210976, 241.6146630437932, 2.2775754076549988, 0.05713906210891133, 0.4801159964190674, 0.4136552999184616],
the coordinate of class 2 is [1.8041703038832744, 0.13208338601876113, 239.81449412002692, 7.532981379357298, 0.19341163078674328, 0.5632924925202089, 17.880204896282795],
the coordinate of class 3 is [3.9468702411594236, 0.1957027940583639, 237.29870892382817, 16.74635573334978, 21.696980203739883, 17.257564011122483, 11.088855810876463],
the number of each class: Counter({0: 1302497, 1: 650133, 2: 96650})
the loss: 59.92451348530257
Since the value of loss has no further changes at the 8 time, loop out!!!

```

K=4:

```

k=4!!!!
this is the time of 1:

the coordinate of class 1 is [  0.654   0.208 239.35   2.8     0.     0.     0.    ],
the coordinate of class 2 is [  0.214   0.    244.3   0.8    0.     0.     0.    ],
the coordinate of class 3 is [  0.116   0.    235.87   0.6    0.     0.     0.    ],
the coordinate of class 4 is [  3.536   0.    240.51   14.6   0.     0.    18.    ],

the number of each class: Counter({3: 691556, 0: 640180, 1: 621299, 2: 96245})
the loss: 108.9159989221449
this is the time of 2:

the coordinate of class 1 is [0.8378295135741781, 0.13795494704616082, 240.0292229217166, 3.622017557564299, 1.2244837389484207, 1.4616545346621264, 0.748203630228998],
the coordinate of class 2 is [0.3833965063520252, 0.10093638006820727, 243.9633001179836, 1.6584308038479145, 0.024775510663947634, 0.35387148538787283, 0.46280937197708996],
the coordinate of class 3 is [0.3601783780975257, 0.09609993246402672, 235.5900299236326, 1.625169099693497, 0.11075900046755675, 0.3842693126915684, 0.19391137201932568],
the coordinate of class 4 is [2.0646107184377644, 0.1348391077512231, 239.51477449406016, 8.644326128324694, 2.1533932176136132, 2.123421675178872, 18.002845756525865],
the number of each class: Counter({1: 733173, 3: 708514, 0: 464763, 2: 142830})
the loss: 89.9697875958857

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this is the time of 10:

the coordinate of class 1 is [3.960614370082879, 0.19566167908345408, 237.29298785450425, 16.801164465034663, 21.88391869613306, 17.203124021786767, 11.167219683215427],
the coordinate of class 2 is [0.39945536328931647, 0.10479387983211237, 243.35447515690186, 1.7345047781413216, 0.025172533760360046, 0.3543585593276797, 0.42770730575918553],
the coordinate of class 3 is [0.7319812646559557, 0.12983044473114902, 238.74657240168563, 3.1860511347505436, 0.11313421451928304, 0.7220876642081092, 0.3956451887733989],
the coordinate of class 4 is [1.8045992915876157, 0.1320635786208522, 239.81446487483964, 7.534682045347454, 0.19333316920652896, 0.5679577291415348, 17.884481400329896],
the number of each class: Counter({1: 809456, 3: 649939, 2: 494153, 0: 95732})
the loss: 56.40273026447742
this is the time of 11:

the coordinate of class 1 is [3.962096226966978, 0.1956610746667789, 237.29168700121133, 16.807140767977184, 21.9077424476664, 17.19418794133623, 11.173118706388669],
the coordinate of class 2 is [0.39850990294712374, 0.10467772182798758, 243.3565239370997, 1.730443903064393, 0.024940206756142398, 0.35268624854223085, 0.4274611590944454],
the coordinate of class 3 is [0.7330115652439175, 0.129973797589014, 238.7535235443355, 3.190451540312986, 0.11336367481326634, 0.7277401938266084, 0.39609189866296474],
the coordinate of class 4 is [1.8046760849863737, 0.13206720015263954, 239.8143949047799, 7.53502897889108, 0.1933350668293486, 0.5691272565579232, 17.884449155997718],
the number of each class: Counter({1: 808926, 3: 649954, 2: 494707, 0: 95693})
the loss: 56.40263510206645
Since the value of loss has no further changes at the 11 time, loop out!!!

```

K=5:

```

k=5!!!!
this is the time of 1:

the coordinate of class 1 is [ 0.37   0.194 243.81   1.6    0.    0.    1.    ],
the coordinate of class 2 is [ 1.74   0.084 240.93   7.2    0.    0.    19.    ],
the coordinate of class 3 is [ 1.042   0.   238.47   4.4    0.    0.    0.    ],
the coordinate of class 4 is [ 0.384   0.19 241.35   1.8    0.    0.    1.    ],
the coordinate of class 5 is [ 0.322   0.07 243.15   1.4    0.    0.    1.    ],

the number of each class: Counter({1: 707904, 3: 508966, 0: 330226, 2: 304562, 4: 197622})
the loss: 95.37356672348414
this is the time of 2:

the coordinate of class 1 is [0.4617609152520224, 0.10544412614392248, 245.22779372308287, 1.975443484159939, 0.03850696189882081, 0.396440619454554, 0.38648985846056944],
the coordinate of class 2 is [2.0252207304944667, 0.13735427685110857, 239.5576332101752, 8.480551035168041, 2.035663027755176, 1.9947817783202242, 17.882080056052796],
the coordinate of class 3 is [1.332729946618718, 0.14450959082223066, 237.90702582725459, 5.712231355491544, 2.72564863640244, 2.7913798952252744, 0.28458364786151916],
the coordinate of class 4 is [0.36192430535633674, 0.11605014873292875, 240.76052702932836, 1.6142182385449921, 0.02473053209841129, 0.4047087624713635, 0.5420244181340207],
the coordinate of class 5 is [0.3075137484692807, 0.09307596320248271, 242.82489783524602, 1.3485593709205377, 0.01340437805507484, 0.313077491372418, 0.43629251803948954],
the number of each class: Counter({1: 708768, 3: 568731, 4: 359880, 0: 255217, 2: 156684})
the loss: 86.40647193354346

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this is the time of 38:

the coordinate of class 1 is [0.40117060141012634, 0.10465529833450843, 243.47857354378223, 1.740419887326305, 0.025042456368066592, 0.35444428467982525, 0.424876878125935],
the coordinate of class 2 is [1.7998923393717456, 0.1318258188396165, 239.816169346082, 7.514372927121998, 0.20309137729416435, 0.4754931265824154, 17.884155223843786],
the coordinate of class 3 is [3.997743113977394, 0.19904775630055319, 237.1740334348148, 16.952207670551985, 36.95755796148511, 2.451730287690728, 11.162994721766857],
the coordinate of class 4 is [3.698072043285604, 0.19091585719154883, 237.73966342876884, 15.718349522835615, 0.8441121336059987, 35.58041496250852, 10.608959611451942],
the coordinate of class 5 is [0.6950695933892157, 0.1277441815938126, 238.89619904571342, 3.0268534825136393, 0.10834927309021491, 0.5179381505837837, 0.4022581698859079],
the number of each class: Counter({0: 775550, 1: 647349, 4: 523926, 2: 55511, 3: 46944})
the loss: 26.859007936220276
this is the time of 39:

the coordinate of class 1 is [0.40102466120881318, 0.10470015343948488, 243.4670148024236, 1.7399559022620434, 0.02505963509767262, 0.3547134291792921, 0.4251395783637419],
the coordinate of class 2 is [1.7998923393717456, 0.1318258188396165, 239.816169346082, 7.514372927121998, 0.20309137729416435, 0.4754931265824154, 17.884155223843786],
the coordinate of class 3 is [3.997743113977394, 0.19904775630055319, 237.1740334348148, 16.952207670551985, 36.95755796148511, 2.451730287690728, 11.162994721766857],
the coordinate of class 4 is [3.698072043285604, 0.19091585719154883, 237.73966342876884, 15.718349522835615, 0.8441121336059987, 35.58041496250852, 10.608959611451942],
the coordinate of class 5 is [0.6972944041715177, 0.1278355951031365, 238.88198883049748, 3.0363329935913086, 0.10889324064848853, 0.5186572149502029, 0.40170558437641957],
the number of each class: Counter({0: 778308, 1: 647347, 4: 521170, 2: 55511, 3: 46944})
the loss: 26.858780558609435
Since the value of loss has no further changes at the 39 time, loop out!!!

```

K=6

```

k=6!!!!
this is the time of 1:

the coordinate of class 1 is [ 1.458   0.148 242.6     6.      0.      0.      19.    ],
the coordinate of class 2 is [ 0.242   0.116 240.24    1.      0.      0.      1.    ],
the coordinate of class 3 is [ 0.75    0.     247.01    3.2     0.      0.      0.    ],
the coordinate of class 4 is [ 1.41    0.198 235.13    6.      0.      0.      17.    ],
the coordinate of class 5 is [ 0.964   0.194 238.01    5.2     0.      2.      1.    ],
the coordinate of class 6 is [ 1.312   0.63  243.45     6.      0.      1.      0.    ],

the number of each class: Counter({1: 809679, 0: 433655, 3: 275491, 2: 255660, 4: 169137, 5: 105658})
the loss: 93.2503311669788

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this is the time of 14:

the coordinate of class 1 is [1.7996488647077293, 0.131770978561613, 239.81614487536783, 7.513140331081024, 0.2030941311034515, 0.4769958421565142, 17.898401409648053],
the coordinate of class 2 is [0.36663530909124203, 0.11390659412562786, 239.50830348933894, 1.640189299893989, 0.026263567836943953, 0.3960472891215302, 0.42703618388620496],
the coordinate of class 3 is [0.4064557855913369, 0.10500844257732589, 243.97984200390135, 1.7344120620298544, 0.022931097989391202, 0.3471744220574705, 0.4188608767753671],
the coordinate of class 4 is [4.001780033963205, 0.19889059507894644, 237.1699355060158, 16.966585973913578, 37.00457058207176, 2.455179390829931, 11.192036709180908],
the coordinate of class 5 is [3.7153031054026626, 0.19064918216494764, 237.72258043661228, 15.788897269572981, 0.852811240652544, 35.76475658901364, 10.70659224619098],
the coordinate of class 6 is [1.79923060733860578, 0.1594652724497122, 239.39867923781912, 7.649639713036066, 0.4040829886021182, 0.9653238627824753, 0.37900132692037303],

the number of each class: Counter({0: 646971, 2: 618843, 1: 555369, 5: 126340, 3: 55354, 4: 46403})
the loss: 25.05479487549482
Since the value of loss has no further changes at the 14 time, loop out!!!

```

K=7

```
k=7!!!!  
  
this is the time of 1:  
  
the coordinate of class 1 is [ 1.254 0. 236.5 5.2 0. 0. 17. ],  
  
the coordinate of class 2 is [ 0.522 0.208 246.18 2.2 0. 1. 1. ],  
  
the coordinate of class 3 is [ 0.77 0.252 242.53 3.2 0. 2. 1. ],  
  
the coordinate of class 4 is [ 1.13 0. 239.42 4.8 0. 0. 0. ],  
  
the coordinate of class 5 is [ 1.144 0.114 241.92 4.8 0. 0. 0. ],  
  
the coordinate of class 6 is [ 0.252 0.256 241.28 1.4 0. 0. 1. ],  
  
the coordinate of class 7 is [ 0.288 0.214 241.73 1.4 0. 1. 0. ],  
  
the number of each class: Counter({0: 708871, 5: 421154, 6: 320559, 1: 229894, 3: 208053, 4: 83239, 2: 77510})  
the loss: 99.6397257964865
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```
this is the time of 21:  
  
the coordinate of class 1 is [1.7997216029678247, 0.13176300189358384, 239.81629397537068, 7.513430150325759, 0.2030297175097577, 0.4771542296247633, 17.890968814004715],  
the coordinate of class 2 is [0.41640394028320493, 0.09939216143843894, 245.15640368941533, 1.7827733666265961, 0.021862912682531255, 0.32092830598159955, 0.36339107048054653],  
the coordinate of class 3 is [3.7157828702006976, 0.1906480695022327, 237.72090952206702, 15.79092849289608, 0.8530191648522215, 35.77012956216181, 10.7082587793994],  
the coordinate of class 4 is [4.001799577258671, 0.19888757610246963, 237.16989648257547, 16.96665402055918, 37.00487778440193, 2.455205679908948, 11.19222083717233],  
the coordinate of class 5 is [1.8302926857704165, 0.160899859261663, 239.61723261798144, 7.776670747245302, 0.4173099824285274, 0.9909477769172476, 0.38096784670347517],  
the coordinate of class 6 is [0.40340487745688397, 0.10992499613950639, 236.9695671836028, 1.807432000176364, 0.03541726412388873, 0.3749476075974499, 0.27348282632194304],  
the coordinate of class 7 is [0.37048471644992226, 0.11442206486368688, 241.41694041064966, 1.6431824275723956, 0.02416543772623676, 0.396371375641385, 0.4949664225036259],  
the number of each class: Counter({6: 656012, 0: 646925, 1: 344695, 5: 179830, 4: 120077, 3: 55353, 2: 46388})  
the loss: 24.009294705195273  
Since the value of loss has no further changes at the 21 time, loop out!!!
```

K=8:

```
k=8!!!!  
this is the time of 1:  
  
the coordinate of class 1 is [ 0.254  0.102 241.05  1.2  0.  1.  0.  ],  
the coordinate of class 2 is [ 0.618  0.36 246.17  2.8  0.  2.  1.  ],  
the coordinate of class 3 is [ 1.728  0.048 238.72  7.2  0.  0.  0.  ],  
the coordinate of class 4 is [ 5.12   0.116 234.21  22.  36.  0.  17.  ],  
the coordinate of class 5 is [ 0.268  0.132 240.06  1.2  0.  0.  0.  ],  
the coordinate of class 6 is [ 0.232  0.048 238.67  1.  0.  0.  1.  ],  
the coordinate of class 7 is [ 0.258  0.072 241.09  1.2  0.  1.  0.  ],  
the coordinate of class 8 is [ 4.126  0.112 238.37  17.2  0.  0.  18.  ],  
  
the number of each class: Counter({7: 641901, 6: 483857, 1: 278103, 5: 199521, 4: 186391, 2: 139926, 0: 63953, 3: 55628})  
the loss: 84.71959834235773
```

```
this is the time of 11:  
  
the coordinate of class 1 is [1.8374734788337133, 0.16087675259299095, 239.64688182033046, 7.805571134159705, 0.420284469869901, 0.9924659616878949, 0.3789063819723639],  
the coordinate of class 2 is [0.42647300599512167, 0.09525929616809253, 246.20598437342528, 1.8102622274765165, 0.020142801863739245, 0.3057942359782246, 0.32283080576508194],  
the coordinate of class 3 is [3.715593697460874, 0.19064253998362, 237.72109130491273, 15.790145277406454, 0.8529551235073501, 35.76766392205889, 10.708539897400525],  
the coordinate of class 4 is [4.001760783833494, 0.19888571738266433, 237.16989142609387, 16.9665109863898, 37.004588647613545, 2.4551613252881452, 11.192836709180988],  
the coordinate of class 5 is [0.3707252952325427, 0.1167880643436881, 240.19935926036345, 1.6556033435377322, 0.025999902804101666, 0.4126087379112601, 0.4891480779511105],  
the coordinate of class 6 is [0.41777662005789723, 0.10535107703935662, 235.85469110475512, 1.8718134211520145, 0.03865464557577066, 0.3578254062516871, 0.17930860731702927],  
the coordinate of class 7 is [0.38621037050887025, 0.10967009065754155, 242.8711387724934, 1.690990097537819, 0.024024566090385713, 0.3660385692715755, 0.4627293249209481],  
the coordinate of class 8 is [1.7997228649336539, 0.1317634392313123, 239.8163239513515, 7.51343397556312, 0.2030291600712307, 0.47702314998021367, 17.89105627967946],  
  
the number of each class: Counter({7: 646916, 6: 470315, 4: 412572, 1: 188390, 0: 117843, 5: 111503, 3: 55351, 2: 46390})  
the loss: 23.54427058603288  
Since the value of loss has no further changes at the 11 time, loop out!!!
```

K=9

```
k=9!!!!  
  
this is the time of 1:  
  
the coordinate of class 1 is [ 0.28    0.266 243.97    1.6    0.    2.    0.    ],  
the coordinate of class 2 is [ 0.364   0.142 241.02    1.6    0.    2.    0.    ],  
the coordinate of class 3 is [ 0.246    0.    242.5    1.    0.    0.    1.    ],  
the coordinate of class 4 is [ 1.594   0.214 240.75    6.6    0.    0.    18.    ],  
the coordinate of class 5 is [ 0.3    0.23 240.83    1.6    0.    2.    0.    ],  
the coordinate of class 6 is [ 0.332    0.    245.13    1.4    0.    0.    1.    ],  
the coordinate of class 7 is [ 0.434    0.158 241.05    1.8    0.    1.    1.    ],  
the coordinate of class 8 is [ 0.146    0.    239.11    0.6    0.    0.    0.    ],  
the coordinate of class 9 is [ 1.824   0.294 238.95    7.6    1.    0.    18.    ],  
  
the number of each class: Counter({8: 358320, 3: 352491, 6: 347239, 2: 298606, 7: 267502, 5: 245906, 0: 79598, 4: 62627, 1: 36991})  
the loss: 91.95588480335971  
  
this is the time of 20:  
  
the coordinate of class 1 is [1.2925894683429064, 0.156908095150609, 241.41086349439507, 5.48694085019612, 0.184150897176802, 0.5602127678188674, 0.6672878227168141],  
the coordinate of class 2 is [2.8908439434417437, 0.19486166677526356, 238.64405453834664, 12.341636801980817, 0.2982016029191373, 28.215579592102692, 0.403173258617319],  
the coordinate of class 3 is [0.33558681440851335, 0.11125948489567261, 241.40277788760113, 1.4952983193468936, 0.019246927801528507, 0.38659494856507565, 0.45963366573645204],  
the coordinate of class 4 is [1.7971328105267226, 0.1316117099988794, 239.81851880262255, 7.502205735375963, 0.2026905879054114, 0.43626920043448414, 17.891704358632275],  
the coordinate of class 5 is [4.743768464922426, 0.18817078027321107, 236.5841241028027, 20.101208613104735, 3.861264181523501, 42.85232692752952, 16.206760824264876],  
the coordinate of class 6 is [0.38559039571858916, 0.09812349481094572, 245.18305172184557, 1.6558785241620877, 0.018062268722201465, 0.31445343104757545, 0.3613870038450876],  
the coordinate of class 7 is [2.2249068679526585, 0.16636477495107477, 237.92952362314756, 9.483988444692947, 0.651719317864132, 0.5245550274904482, 0.2862920510670021],  
the coordinate of class 8 is [0.3972965225617891, 0.10936457822811285, 236.91729270433058, 1.781531167010408, 0.033873964234017576, 0.37740064055073685, 0.26290504576176527],  
the coordinate of class 9 is [3.939535867327044, 0.19806585415623193, 237.24013857198517, 16.69888373680626, 37.02402285417478, 1.5702598920362847, 11.097111692359062],  
  
the number of each class: Counter({3: 645361, 2: 622357, 5: 332509, 7: 174913, 0: 114351, 8: 53891, 6: 53591, 1: 30794, 4: 21603})  
the loss: 21.542852954878363  
Since the value of loss has no further changes at the 20 time, loop out!!!
```

K=10

```
k=10!!!!  
  
this is the time of 1:  
  
the coordinate of class 1 is [ 1.844  0.106 241.98   7.6   0.   0.   18.   ],  
  
the coordinate of class 2 is [ 1.524  0.058 239.28   6.4   0.   0.   17.   ],  
  
the coordinate of class 3 is [ 1.808  0.062 235.2    7.6   0.   2.   17.   ],  
  
the coordinate of class 4 is [ 2.616  0.22  242.03  10.8   0.   2.   19.   ],  
  
the coordinate of class 5 is [ 0.786  0.102 241.75   3.4   0.   1.   0.   ],  
  
the coordinate of class 6 is [ 0.944  0.138 244.52   3.8   0.   0.   0.   ],  
  
the coordinate of class 7 is [ 1.11   0.41 241.95   4.8   1.   0.   12.   ],  
  
the coordinate of class 8 is [ 5.548  0.322 238.61  23.4   0.   69.   18.   ],  
  
the coordinate of class 9 is [ 3.032  0.184 236.1   12.8   0.   0.   18.   ],  
  
the coordinate of class 10 is [ 1.872  0.07  236.23   7.8   0.   0.   18.   ],  
  
the number of each class: Counter({4: 980484, 5: 345559, 0: 207378, 1: 190341, 8: 95585, 3: 66134, 9: 60999, 6: 40939, 2: 38682, 7: 23179})  
the loss: 76.47928278431596
```

```
this is the time of 17:  
  
the coordinate of class 1 is [1.6167897368182088, 0.10502617280959019, 243.2940694145795, 6.614677689862134, 0.11492171174172446, 0.3731124504073412, 18.515697022926194],  
the coordinate of class 2 is [1.567648131445207, 0.11209235290580512, 239.50494374042162, 6.520820179789955, 0.11462373350169869, 0.4133143922311416, 17.96051682150266],  
the coordinate of class 3 is [1.5962870472171755, 0.11100793391376576, 234.70289706712506, 6.78370724749682, 0.13496567913707544, 0.4312394140195525, 17.030591626303746],  
the coordinate of class 4 is [2.341970520333872, 0.26887231397620326, 238.99627360445194, 9.851914994376328, 0.2556088328606168, 0.5349553069318652, 28.37323151601255],  
the coordinate of class 5 is [0.6937608686841945, 0.12722585674892878, 238.86984307491156, 3.0190973140185715, 0.10900428205608162, 0.5205949722988216, 0.3439789737345357],  
the coordinate of class 6 is [0.3999486615763557, 0.10441902869830338, 243.4642284446441, 1.7343972863377846, 0.025102143363684628, 0.3548944206407744, 0.399375062164393],  
the coordinate of class 7 is [0.0678979635789274, 0.26200708320371535, 240.83725813013123, 4.645327717820598, 0.06784081935437555, 0.4577281102682524, 10.963339634832133],  
the coordinate of class 8 is [3.703422212628159, 0.190305321100919, 237.73723367512372, 15.740347544522248, 0.8511818672423098, 35.806886130599025, 10.527879114948732],  
the coordinate of class 9 is [3.998823693405004, 0.19866192364090599, 237.17467731132, 16.953724723474554, 37.0467061315375, 2.458172667861475, 11.129781494958273],  
the coordinate of class 10 is [3.053245419881463, 0.1715358274172665, 238.0870075066939, 12.89867879517996, 0.7297996516566679, 0.9493068782529869, 17.575948013322606],  
the number of each class: Counter({5: 776192, 4: 516179, 1: 266238, 0: 164717, 9: 98134, 2: 67581, 8: 55239, 7: 46322, 6: 41785, 3: 16893})  
the loss: 21.21934297158724  
Since the value of loss has no further changes at the 17 time, loop out!!!
```

K=11

```
k=11!!!!  
  
this is the time of 1:  
  
the coordinate of class 1 is [ 0.506 0.166 244.94 2.2 1. 0. 1. ],  
the coordinate of class 2 is [ 0.426 0.304 237.67 2.2 0. 1. 0. ],  
the coordinate of class 3 is [ 0.818 0.304 241.3 3.8 0. 1. 1. ],  
the coordinate of class 4 is [ 1.266 0.102 242.44 5.2 0. 0. 18. ],  
the coordinate of class 5 is [ 0.358 0.142 247.05 1.6 0. 0. 1. ],  
the coordinate of class 6 is [ 0.432 0.22 240.79 2. 0. 0. 1. ],  
the coordinate of class 7 is [ 0.292 0.062 246.28 1.2 0. 0. 0. ],  
the coordinate of class 8 is [ 0.438 0.318 242. 2.2 0. 1. 0. ],  
the coordinate of class 9 is [ 0.228 0.132 241.97 1. 0. 0. 1. ],  
the coordinate of class 10 is [ 1.844 0.05 239.83 7.6 0. 0. 19. ],  
the coordinate of class 11 is [ 3.69 0.414 241.29 16. 32. 1. 19. ],  
  
the number of each class: Counter({9: 450186, 8: 269199, 5: 227826, 3: 223067, 1: 201535, 7: 173506, 2: 173192, 0: 125432, 6: 95662, 10: 57359, 4: 52316})  
the loss: 55.208741358585385
```

```
this is the time of 37:  
  
the coordinate of class 1 is [1.3659810526904718, 0.15385282846459994, 241.36172616994, 5.783979337802778, 0.20936325746627008, 0.5043590150024709, 0.5810124103721247],  
the coordinate of class 2 is [0.422345514875624, 0.10440071295652861, 235.41987265430296, 1.892881644732328, 0.03765441786426922, 0.3411317624375042, 0.1520749753547966],  
the coordinate of class 3 is [3.72735407964659, 0.19006306995866928, 237.7219574868263, 15.837544557919692, 0.8606512563693223, 36.00730421851423, 10.7138670807181761],  
the coordinate of class 4 is [1.5182889163686661, 0.11966647536670146, 240.9185429113501, 6.2841852678797405, 0.10417474277373401, 0.39040785874699246, 17.749482948676025],  
the coordinate of class 5 is [0.41348630494552685, 0.09264751331221646, 246.9927063829968, 1.7485730692929713, 0.015435213865590089, 0.29493961646886857, 0.305998329446977361],  
the coordinate of class 6 is [0.3638537629752846, 0.11733895444176262, 239.3865663928318, 1.6329023282292168, 0.026922783932129726, 0.4179025487436702, 0.44668968033454015],  
the coordinate of class 7 is [0.3697996125328423, 0.10319268287745448, 243.91156102606482, 1.6077804487995055, 0.02035724066579436, 0.33723167222847716, 0.4022490876782738],  
the coordinate of class 8 is [2.2489902931621533, 0.17225543074092814, 237.95809268464362, 9.603354338721772, 0.648009706837841, 1.7717523199731534, 0.2859603115581823],  
the coordinate of class 9 is [0.33746745664498395, 0.11043259703223873, 241.6799947134432, 1.5088936861940034, 0.01879208631080335, 0.382008237278391, 0.4760068279355162],  
the coordinate of class 10 is [2.503385735878687, 0.16228188287691997, 237.07483327684884, 10.58771536305759, 0.4662492536590876, 0.7288429160816967, 18.234552760251095],  
the coordinate of class 11 is [4.003455317142168, 0.1985691328242615, 237.17352202854929, 16.970743474870866, 37.07717700832532, 2.460667839587906, 11.178205430504416],  
  
the number of each class: Counter({3: 461754, 8: 393437, 6: 295793, 5: 249379, 9: 185904, 4: 115130, 0: 107241, 1: 89217, 10: 55133, 7: 50570, 2: 45722})  
the loss: 20.72330327208462  
Since the value of loss has no further changes at the 37 time, loop out!!!
```

K=12

```
k=12!!!!  
  
this is the time of 1:  
  
the coordinate of class 1 is [ 0.392 0.35 239.96 2.2 0. 2. 1. ],  
the coordinate of class 2 is [ 0.432 0.228 240.98 2. 0. 1. 1. ],  
the coordinate of class 3 is [ 1.954 0.19 241.09 8. 0. 0. 29. ],  
the coordinate of class 4 is [ 0.33 0.09 243.57 1.4 0. 0. 0. ],  
the coordinate of class 5 is [ 0.226 0.12 240.76 1. 0. 0. 0. ],  
the coordinate of class 6 is [ 0.464 0.18 237.27 2. 0. 1. 0. ],  
the coordinate of class 7 is [ 1.744 0.144 240.96 7.4 0. 0. 18. ],  
the coordinate of class 8 is [ 0.202 0.062 244.27 1. 0. 0. 0. ],  
the coordinate of class 9 is [ 0.696 0.098 242.65 2.8 0. 0. 1. ],  
the coordinate of class 10 is [ 0.35 0.204 242.46 1.6 0. 0. 1. ],  
the coordinate of class 11 is [ 0.43 0. 240.38 1.8 0. 0. 0. ],  
the coordinate of class 12 is [ 0.41 0. 247.28 2. 0. 0. 0. ],  
  
the number of each class: Counter({6: 691403, 5: 187549, 4: 162555, 9: 155228, 8: 149445, 3: 145259, 10: 134000, 7: 126566, 11: 100121, 1: 95997, 0: 82964, 2: 18193})  
the loss: 92.2676137953014
```

```
this is the time of 38:  
  
the coordinate of class 1 is [3.7256357752535587, 0.19041157179158769, 237.71652433594946, 15.830675672740552, 0.8578719892274613, 35.884368959450946, 10.762569771735118],  
the coordinate of class 2 is [1.397656664563937, 0.15310529041248006, 241.2725615049273, 5.915118019791023, 0.21996779994539173, 0.47974315278078544, 0.5347468717929404],  
the coordinate of class 3 is [2.3718959764475116, 0.26725590255729337, 238.96958725394026, 9.982127806961781, 0.26479247243549037, 0.5363389713098193, 28.221208797552386],  
the coordinate of class 4 is [0.35443301845738423, 0.10930576888616139, 242.76124718401175, 1.5616126513578246, 0.01950695031103602, 0.36905447610270586, 0.46782121188848785],  
the coordinate of class 5 is [0.3919855593543619, 0.11843405497331194, 238.74055273424736, 1.755326974113795, 0.03289454327191842, 0.42373350123869435, 0.41205858641731935],  
the coordinate of class 6 is [2.280652523128672, 0.17387220353237956, 237.86754857022598, 9.744936921783106, 0.6661900756938604, 1.910071488645921, 0.2872161480235492],  
the coordinate of class 7 is [1.7840025531833175, 0.12807526492453583, 239.8400788502025, 7.445691503043016, 0.20187932080241092, 0.47671331624859875, 17.60558397718648],  
the coordinate of class 8 is [0.39076591472958194, 0.09868102923659913, 244.79098580560412, 1.6880753158699712, 0.021039327157636314, 0.3157927587265095, 0.35336707254276783],  
the coordinate of class 9 is [4.002719837954155, 0.1987305807245039, 237.17045376449101, 16.96962364132914, 37.02233555784638, 2.4563145425279873, 11.194726276382182],  
the coordinate of class 10 is [0.332983653497619, 0.11171267961786316, 240.9091785224173, 1.4886869807464886, 0.01942367345420965, 0.3918884161401182, 0.48224816314894065],  
the coordinate of class 11 is [0.42077721026875625, 0.10394506334204758, 235.0692834640394, 1.8894483544472755, 0.03724110195053288, 0.33574636369729877, 0.13569274080032173],  
the coordinate of class 12 is [0.416336664268421, 0.09176094545260678, 247.62058970874392, 1.755719881684871, 0.013390358941562075, 0.29454792549364456, 0.31138913315746],  
  
the number of each class: Counter({6: 629802, 9: 321781, 3: 313360, 7: 193457, 4: 168617, 1: 106167, 11: 75610, 10: 74238, 8: 55293, 5: 47589, 0: 46043, 2: 17323})  
the loss: 21.85464177691856  
Since the value of loss has no further changes at the 38 time, loop out!!!
```

K=13

```
this is the time of 1:  
the coordinate of class 1 is [ 2.642 0.178 240.25 11. 0. 0. 28. ],  
the coordinate of class 2 is [ 0.262 0. 240.94 1.2 0. 0. 0. ],  
the coordinate of class 3 is [ 1.486 0.228 240.57 6.2 0. 1. 18. ],  
the coordinate of class 4 is [ 0.548 0.062 239.53 2.2 0. 0. 1. ],  
the coordinate of class 5 is [ 0.196 0.094 239.33 0.8 0. 1. 0. ],  
the coordinate of class 6 is [ 0.224 0. 243.35 1. 0. 0. 0. ],  
the coordinate of class 7 is [ 1.27 0. 240.47 5.2 0. 0. 19. ],  
the coordinate of class 8 is [ 0.418 0.24 242.89 2. 0. 1. 0. ],  
the coordinate of class 9 is [ 2.798 0.344 237.77 11.8 0. 39. 0. ],  
the coordinate of class 10 is [ 1.322 0.204 231.34 5.8 2. 0. 16. ],  
the coordinate of class 11 is [ 1.386 0.102 239.75 5.8 0. 0. 18. ],  
the coordinate of class 12 is [ 3.572 0.078 240.79 14.8 0. 0. 18. ],  
the coordinate of class 13 is [ 0.424 0.22 241.41 2. 0. 0. 1. ],  
the number of each class: Counter({5: 357561, 2: 227717, 3: 227353, 10: 212874, 7: 208558, 1: 184806, 4: 171102, 12: 166286, 11: 1037791, 6: 72718, 9: 52057, 8: 46799, 0: 17658})  
the loss: 61.46252032146028
```

```
this is the time of 21:  
the coordinate of class 1 is [2.334796213017758, 0.2684010650887576, 238.9934562130182, 9.821526627218907, 0.25118343195266274, 0.5350887573964497, 28.36958579881657],  
the coordinate of class 2 is [0.3435294692906974, 0.11462464209380677, 240.2246393717246, 1.5402874847753866, 0.02226327781586482, 0.406122716457636, 0.46333981933298385],  
the coordinate of class 3 is [2.442184041332025, 0.1575429768149446, 239.82281362060152, 10.22527734147316, 0.38482055537444804, 0.8344545535370299, 17.931353663475882],  
the coordinate of class 4 is [2.254027288051556, 0.17238588001983063, 237.9352519583522, 9.625772930094309, 0.6529300941993059, 1.8007734258800199, 0.26217154189390185],  
the coordinate of class 5 is [0.4176096467713236, 0.1056450311568915, 235.93402139235195, 1.8696015960765393, 0.03762557238154668, 0.35034584589423357, 0.1746807407342304],  
the coordinate of class 6 is [0.40537503935138564, 0.09444344171300746, 246.2608829068639, 1.7233186605620627, 0.01747477369505305, 0.3028316423746693, 0.315473796609577],  
the coordinate of class 7 is [1.5020367523719274, 0.11165448247005921, 242.29989664102186, 6.173003780782888, 0.09128912242874751, 0.35678448786040884, 18.046021508618983],  
the coordinate of class 8 is [1.3579519951995185, 0.15385798579858068, 241.30783887479538, 5.751113293147526, 0.2081117202629354, 0.5034958041258671, 0.5559283201047377],  
the coordinate of class 9 is [3.7284530508176457, 0.18977307895199744, 237.71764550729964, 15.84210040443103, 0.8612405486196588, 36.091898188851765, 10.679818005978548],  
the coordinate of class 10 is [4.003484014032015, 0.19838235454495898, 237.17344202701, 16.96963847538056, 37.11472817492775, 2.4643110311358307, 11.163894796153915],  
the coordinate of class 11 is [1.4555860477905953, 0.12321885151541487, 237.60574810892788, 6.119077558363007, 0.10452039280204697, 0.4079166297696226, 16.958888148358742],  
the coordinate of class 12 is [3.371681702730925, 0.17981622004764808, 236.3983744511617, 14.337785741006847, 0.9328397881431019, 0.8811356789856071, 17.291047274016027],  
the coordinate of class 13 is [0.35314743310728935, 0.1073432531311976, 242.90642668522844, 1.552729172107104, 0.01941324976059894, 0.3593114178123319, 0.44853602623255273],  
the number of each class: Counter({12: 447751, 1: 397414, 6: 265422, 10: 214673, 5: 180631, 4: 113945, 7: 110100, 2: 101227, 9: 55019, 11: 50544, 3: 50160, 8: 45491, 0: 16903})  
the loss: 18.451094027424304  
Since the value of loss has no further changes at the 21 time.loop out!!!
```

K=14

```
the coordinate of class 1 is [ 0.33  0.244 241.42  1.6  1.  0.  0.  ],  
the coordinate of class 2 is [ 0.358  0.1  238.83  1.6  0.  0.  0.  1.  ],  
the coordinate of class 3 is [ 0.396  0.076 241.27  1.6  0.  0.  0.  1.  ],  
the coordinate of class 4 is [ 0.542  0.236 236.1   2.4  0.  2.  0.  0.  ],  
the coordinate of class 5 is [ 0.214  0.  239.46  0.8  0.  0.  0.  0.  ],  
the coordinate of class 6 is [ 2.068  0.  235.13  8.8  0.  0.  0.  17.  ],  
the coordinate of class 7 is [ 1.534  0.102 244.71  6.2  0.  0.  0.  19.  ],  
the coordinate of class 8 is [ 1.362  0.206 238.38  5.6  0.  1.  18.  ],  
the coordinate of class 9 is [ 0.312  0.216 239.31  1.6  0.  1.  0.  0.  ],  
the coordinate of class 10 is [ 0.478  0.062 244.63  2.2  0.  0.  0.  0.  ],  
the coordinate of class 11 is [ 0.162  0.  243.75  0.6  0.  0.  0.  1.  ],  
the coordinate of class 12 is [ 2.46  0.054 238.43  10.4  0.  0.  0.  0.  ],  
the coordinate of class 13 is [ 0.218  0.124 239.19  1.  0.  0.  0.  0.  ],  
the coordinate of class 14 is [ 1.672  0.13 241.03  6.8  0.  0.  0.  18.  ],  
the number of each class: Counter({0: 291395, 13: 271478, 2: 265389, 7: 180407, 5: 170262, 10: 166564, 0: 141162, 3: 98915, 8: 97721, 11: 96345, 6: 87904, 1: 74849, 4: 62175, 12: 447}  
the loss: 86.23647150270416
```

```
this is the time of 50:  
  
the coordinate of class 1 is [0.33037934339016034, 0.10922507046788694, 241.6440278242815, 1.470271623993472, 0.01795238083069052, 0.3767780025299441, 0.46127780063529795],  
the coordinate of class 2 is [2.746543603076598, 0.1900486765608617, 238.7945686356148, 11.737977106127888, 0.2667099989166937, 27.323619687285596, 5.932401689957751],  
the coordinate of class 3 is [1.2865674859682563, 0.1556448659189675, 241.8392397620278, 5.452474238029458, 0.1890300036626048, 0.5350372694786233, 0.6569921105512715],  
the coordinate of class 4 is [4.522622276850054, 0.191952276800237336, 236.85871111299474, 19.1602180222937888, 1.4106128676782232, 41.952693057557, 15.394761380011868],  
the coordinate of class 5 is [0.3763197887384229, 0.11870796165813259, 239.33591735322824, 1.686337361420184, 0.029024132014165236, 0.4257602862254025, 0.4358568710728179],  
the coordinate of class 6 is [4.410696138034865, 0.20016333738637052, 236.64682328759105, 18.71151062474695, 36.922673846332, 2.614006137455851, 17.632215853164265],  
the coordinate of class 7 is [1.596336477807083, 0.11534007825047078, 242.26562980106893, 6.567037165437083, 0.11008483030401653, 0.38215026071698943, 18.458851288727264],  
the coordinate of class 8 is [2.9313206541898675, 0.17757268588770458, 237.94872382397142, 12.384800282326558, 0.6358202663968977, 0.5767492834268665, 18.55383577811499],  
the coordinate of class 9 is [2.1372727685742587, 0.163932663756874, 238.1603170482388, 9.095374081225355, 0.48134867193457836, 0.49210624523372976, 0.2777173824868866],  
the coordinate of class 10 is [0.40488205782610015, 0.09232138237247568, 246.99454681327381, 1.713512568611505, 0.014386602803901688, 0.28646470649931827, 0.30679474181029964],  
the coordinate of class 11 is [0.3607161327273681, 0.10237268996276307, 243.89672522882879, 1.5697469422616128, 0.019042874426832865, 0.3348448339552176, 0.39480667364803723],  
the coordinate of class 12 is [3.302414502834803, 0.19672742865310436, 238.06648196674385, 13.994873565169375, 37.00424031635619, 2.174138834627662, 0.39777978941350234],  
the coordinate of class 13 is [0.40392128377981407, 0.10360265945720287, 235.37238678161293, 1.815557592564578, 0.035679890465637076, 0.34661128064699537, 0.13692955687316524],  
the coordinate of class 14 is [1.4787351781559999, 0.12853314558588938, 237.89637031141186, 6.215190400391664, 0.10848536794416555, 0.4235827109097588, 16.88331088526999],  
the number of each class: Counter({0: 391936, 10: 296431, 6: 282673, 4: 245762, 13: 244995, 7: 118962, 9: 114690, 2: 101673, 12: 86339, 8: 59467, 5: 34531, 1: 29256, 3: 21577, 11: 28}  
the loss: 15.439975476818226
```

K=15

```
this is the time of 31:  
the coordinate of class 1 is [4.746124231640238, 0.188284697508896, 236.57882839580458, 28.111614364283273, 3.9208905855710126, 42.831908305217915, 16.19314137819476],  
the coordinate of class 2 is [2.6305418658613005, 0.17386092593274693, 237.99166513283951, 11.234429671098857, 1.143972597694376, 0.5106257596405289, 0.2738757320172369],  
the coordinate of class 3 is [3.9398510539165277, 0.19776785880686593, 237.24507091339467, 16.696419852023308, 37.096595038857934, 1.5519317144081852, 11.085972087380212],  
the coordinate of class 4 is [0.29882496828878113, 0.10510017152905889, 240.61773642903154, 1.3403518507840515, 0.01463762684561845, 0.3561426141685166, 0.4207002421586716],  
the coordinate of class 5 is [0.8245441794981892, 0.17730771760836317, 241.19164736285805, 3.6043110536825975, 0.09543051803124633, 0.7619053212733466, 1.1614706918830824],  
the coordinate of class 6 is [0.3955369439664033, 0.0910240699701572, 247.44893791109415, 1.671420614133589, 0.011566859052607877, 0.2816933123170457, 0.30554995911304944],  
the coordinate of class 7 is [0.3746799329328577, 0.10030431004926718, 244.53622371676735, 1.618605022520643, 0.020801211717021806, 0.32550100741589605, 0.3546385748794919],  
the coordinate of class 8 is [1.5845174603174823, 0.14541289198606394, 242.98990572977174, 6.637138985675554, 0.22919086333720481, 0.4329268292682927, 0.30764614789005035],  
the coordinate of class 9 is [1.5183773068203874, 0.1197806099938504, 240.93440886063485, 6.2841985381518795, 0.10409843013412214, 0.3987798905897158, 17.749471314031858],  
the coordinate of class 10 is [0.3659603264528733, 0.10207895298610924, 234.76729329852049, 1.6606368129793427, 0.032464653431203506, 0.33596072056094717, 0.12581908586235775],  
the coordinate of class 11 is [1.4759630113824478, 0.15246638428419496, 238.19549784544278, 6.293109519078419, 0.17225330753542853, 0.5461834788823232, 0.35595879307640016],  
the coordinate of class 12 is [0.35249985975180603, 0.11286448991349973, 238.36972769106129, 1.5868303148384941, 0.029004844248686594, 0.39296787937138483, 0.3226390921013729],  
the coordinate of class 13 is [2.49066221495216, 0.1612320523444111, 237.05288932771876, 10.533424448198808, 0.463867933665598, 0.5677388805785435, 18.23596956199973],  
the coordinate of class 14 is [0.32585060788944864, 0.10513455850673326, 242.51479835821715, 1.4405486392539266, 0.01568234961568235, 0.34778143839632514, 0.424340197802981],  
the coordinate of class 15 is [2.8874635509104363, 0.1948780648129866, 238.66171793860534, 12.326667981331743, 0.29155985012817986, 28.32156780878617, 6.323999211208946],  
the number of each class: Counter({8: 460111, 13: 309099, 3: 278271, 6: 212785, 12: 185837, 11: 132189, 4: 84497, 5: 84277, 9: 61828, 10: 57073, 2: 53657, 7: 51465, 14: 30425, 1: 2}  
the loss: 18.250564244454935  
since the value of loss has no further changes at the 31 time, loop out!!!
```

K=16

```
the coordinate of class 8 is [1.05691607080464337, 0.262754305340559, 240.84010231230846, 4.598002128483081, 0.061967879256965945, 0.44688467492260064, 11.015407314241486],  
the coordinate of class 9 is [1.5970504827906014, 0.11097428016353926, 234.76259735552495, 6.785052338562443, 0.13487691014005276, 0.42633456084901555, 17.043306173340678],  
the coordinate of class 10 is [1.6170639100284405, 0.10495596626680238, 243.32033696339866, 6.615343320620014, 0.11517932275639253, 0.37155036331361674, 18.519074732658915],  
the coordinate of class 11 is [2.3404746325272696, 0.26878828828828844, 238.99749881460448, 9.845329540066352, 0.25568990042674256, 0.5142247510668563, 28.374348032242768],  
the coordinate of class 12 is [1.5672314305325494, 0.11201979692956274, 239.53560270360956, 6.518119179166166, 0.11426181608134821, 0.41132078302520186, 17.96574358512717],  
the coordinate of class 13 is [0.3837868174568727, 0.0930702972306747, 246.3151295345774, 1.633720168189038, 0.015311004784688996, 0.2928229650717704, 0.3067072640278382],  
the coordinate of class 14 is [3.0477634910330123, 0.1718058400778827, 238.09760529901628, 12.875768887445963, 0.7293171305688549, 1.0584374746409153, 17.611498823338472],  
the coordinate of class 15 is [0.3486548293448348, 0.1867899995443417, 242.9423401346279, 1.5327822728199693, 0.018751794511869983, 0.35805695951581223, 0.42880972021566044],  
the coordinate of class 16 is [0.3508969526632385, 0.10181404123433545, 235.84806004196702, 1.5879588811672802, 0.030945001636283134, 0.33663156678922745, 0.1508845554122471],  
the number of each class: Counter({14: 438763, 4: 402567, 11: 266607, 12: 172535, 9: 162847, 15: 103872, 13: 98587, 0: 70595, 8: 68931, 6: 68627, 1: 54501, 7: 41343, 3: 33874, 2: 285}  
the loss: 15.40208860913976  
since the value of loss has no further changes at the 46 time, loop out!!!  
  
the coordinate of class 1 is [1.378581941611889, 0.14934957285679476, 242.7625153671723, 5.800188256770749, 0.19858236946817462, 0.5228689190923742, 0.35671805696193504],  
the coordinate of class 2 is [3.9810700891710287, 0.19820531356647458, 237.19824630288852, 16.872742284687014, 37.12133499688085, 2.1397563392169094, 11.10577593428088],  
the coordinate of class 3 is [4.335735578947359, 0.1989007017543853, 237.12305228070258, 18.400294736842028, 1.788701754385965, 38.47533333333333, 16.779894736842106],  
the coordinate of class 4 is [2.519908893709313, 0.1718380723456639, 238.14844667878202, 10.743612593070424, 0.9401125637568154, 0.5142756639502843, 0.2202028492700944],  
the coordinate of class 5 is [0.3411121878254, 0.11444282771661711, 240.2785656675734, 1.5282724451424157, 0.022228351210930804, 0.4055593240553696, 0.4372495086456012],  
the coordinate of class 6 is [2.671594056962323, 0.19864899550816908, 238.75317685966724, 11.410385507675553, 0.3735623673429093, 30.358260526185894, 0.5546177007749642],  
the coordinate of class 7 is [1.3323003305114038, 0.15353678974834777, 238.60670039429542, 5.689861417140219, 0.16067493911631683, 0.605357764119216, 0.35431404383625187],
```

K=17

```
this is the time of 43:  
  
the coordinate of class 1 is [1.6167239480494018, 0.10499677454959755, 243.3163266576786, 6.614112265297485, 0.11485914715657539, 0.3702951961637989, 18.51864138633047],  
the coordinate of class 2 is [0.4138005916399001, 0.09151637299035333, 247.5665206430894, 1.7453118971058597, 0.013414790996784566, 0.28526045016077173, 0.29692604501607717],  
the coordinate of class 3 is [2.342507427353974, 0.2689478605669647, 238.9972077883652, 9.85413978128029, 0.2545422264307273, 0.54471207906729, 28.374208439367933],  
the coordinate of class 4 is [1.0578689802042434, 0.2629015536518095, 240.84337011761474, 4.681752093316017, 0.06250967506897052, 0.4447751802913702, 11.016915928561057],  
the coordinate of class 5 is [1.566393939280089, 0.11211063743478586, 239.53188725168476, 6.5148246500322955, 0.11422068141782384, 0.41827831384583025, 17.965264292609273],  
the coordinate of class 6 is [3.047468198426929, 0.1704706137362969, 238.07663972667478, 12.872702875662911, 0.735307301665944, 0.6312627732705766, 17.607615449722342],  
the coordinate of class 7 is [1.3804199527481137, 0.1529379928314305, 241.46304241589817, 5.834453320567771, 0.20474922458586403, 0.5541094455913592, 0.36926667265056995],  
the coordinate of class 8 is [0.4024317630758703, 0.11857419961403315, 238.6425310505216, 1.7980219209621903, 0.03504626651491909, 0.42454475728635754, 0.3591159879261715],  
the coordinate of class 9 is [0.38435320470033224, 0.09868708411706248, 244.71919083590862, 1.6543779798705422, 0.020685435754302935, 0.31608620027101914, 0.343218453572801],  
the coordinate of class 10 is [2.881338018410402, 0.19455686429773134, 238.66136989013185, 12.380966769558263, 0.2898149064634267, 28.332838430829128, 6.2539589716585835],  
the coordinate of class 11 is [4.743684996542975, 0.1882383037566257, 236.58219774141608, 20.10135976831331, 3.908135515095644, 42.80106015210878, 16.198156257202122],  
the coordinate of class 12 is [1.5938535111785497, 0.111006070886568155, 234.75342580701596, 6.77165088475968, 0.13444924406047515, 0.4305790671881385, 17.041401552740645],  
  
the coordinate of class 13 is [0.350625006343266, 0.10908199279408015, 242.6865269778807, 1.5454227138940093, 0.019254922358672485, 0.37035991576169697, 0.44507383538088727],  
the coordinate of class 14 is [3.939288163417575, 0.19765197276373472, 237.24347001212598, 16.693752448465904, 37.11528775300812, 1.5530640798432982, 11.066374405372633],  
the coordinate of class 15 is [2.251512946654518, 0.16613041808585067, 237.84357546310167, 9.600109322806011, 0.6787326652495191, 0.52493167324628, 0.23291831156999696],  
the coordinate of class 16 is [0.40651258715800087, 0.10357441684635009, 235.00650247822614, 1.8298171431770633, 0.035311248634874406, 0.3505922544874128, 0.11619669809548879],  
the coordinate of class 17 is [0.33015649859854546, 0.1134765870101418, 240.82801177981815, 1.4759526159295537, 0.019113803117107517, 0.3904866105633559, 0.45239048661056336],  
the number of each class: Counter({16: 316465, 12: 315949, 4: 266237, 8: 198770, 0: 163075, 7: 160639, 6: 100201, 5: 96882, 1: 78198, 15: 71081, 11: 68529, 13: 53605, 14: 49427, 3:  
the loss: 15.173236474609162  
Since the value of loss has no further changes at the 43 time, loop out!!!
```

K=18

```
this is the time of 25:  
  
the coordinate of class 1 is [3.016470110965287, 0.24906884619973668, 238.1691767092232, 13.48753132084473, 19.394344350316192, 0.7170981983056914, 13.274310941415106],  
the coordinate of class 2 is [0.3004080313976765, 0.10238157870549118, 240.14448156217233, 1.3470201658117167, 0.016401955918307322, 0.2753037739664332, 0.4339555874188864],  
the coordinate of class 3 is [0.3573080474682481, 0.10176346014423479, 234.5403785248211, 1.6257145037586478, 0.0312130346853894, 0.33172434845651927, 0.1088081802338077],  
the coordinate of class 4 is [0.39864046172548607, 0.09913377885783637, 248.1745382746085, 1.6795423248277621, 0.008586472255974078, 0.2875658161198866, 0.38324017829980154],  
the coordinate of class 5 is [2.7157116672246455, 0.1690833612320061, 238.19417852360328, 11.523677602946252, 0.2602109139604955, 0.49807499163039837, 0.2349347171974657],  
the coordinate of class 6 is [3.9957972875659986, 0.19425556088974258, 237.1996279404695, 16.88562978075242, 38.07461193791086, 1.7185749719955192, 10.930648903824611],  
the coordinate of class 7 is [4.739207881130921, 0.187849084726815, 236.5891844054294, 20.08135451115549, 3.677581629326005, 42.88779169965998, 16.2778972899386],  
the coordinate of class 8 is [2.8936894385551946, 0.19475925925925713, 238.64363008768518, 12.352964271692164, 0.2797735898442612, 28.271495877502943, 6.402892291584871],  
the coordinate of class 9 is [0.29919129958208347, 0.08034953121665361, 241.95303238598748, 1.3069972345756673, 0.014044673525141932, 0.08746020257464762, 0.43356497073503386],  
the coordinate of class 10 is [0.3642578119302389, 0.10304232297820372, 243.6362297181403, 1.5875054692631863, 0.019826077444760445, 0.2796525195070371, 0.408558484696026],  
the coordinate of class 11 is [1.5837787440679933, 0.1550611190817794, 237.63114314093446, 6.764833903542701, 0.2551594746716698, 0.5651694073501821, 0.288798145900011],
```

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the coordinate of class 12 is [1.831119984045784, 0.12270553545865779, 239.77421049250708, 7.631307366099197, 0.13804288170036869, 0.4355002727696753, 18.252327607093],
the coordinate of class 13 is [1.0041647341510362, 0.15293934229275555, 240.59677446844327, 4.296803665726199, 0.13087088932971977, 0.3919801983738929, 0.4659690983766869],
the coordinate of class 14 is [1.5957973177544327, 0.14693951088463109, 243.10076075136902, 6.680198716445371, 0.22828937549305986, 0.4006097951003177, 0.2997590669708535],
the coordinate of class 15 is [0.355820077294689, 0.11107659903381502, 237.90094492753482, 1.602052173913275, 0.030483091787439614, 0.39142995169082123, 0.2817294685990338],
the coordinate of class 16 is [0.4455137577174022, 0.21050506808104086, 241.73972620831802, 2.06062619886904, 0.03352166119851993, 1.7317533359189108, 0.5103720086791543],
the coordinate of class 17 is [0.378599208796182694, 0.09456475350400738, 245.54864381390034, 1.6191189892580344, 0.01807185714627288, 0.2983370385421398, 0.3061777384680356],
the coordinate of class 18 is [1.073979540109347, 0.26198465545820687, 240.75315226142686, 4.669699265924812, 0.04958560265214303, 0.444091877811982, 11.063106796116505],
the number of each class: Counter({11: 606736, 8: 238849, 9: 220106, 1: 217131, 16: 126319, 14: 102831, 15: 95194, 12: 71574, 2: 52218, 5: 49983, 3: 49667, 13: 46893, 10: 45284, 17: 18.67037667776227
Since the value of loss has no further changes at the 25 time, loop out!!!

```

K=19

```

this is the time of 29:

the coordinate of class 1 is [2.11238739255015, 0.16597281120662097, 241.06150493473382, 8.917669531996179, 0.7675262655205348, 0.4866284622731614, 0.2703279210442534],
the coordinate of class 2 is [0.4002098869527419, 0.0907149772031714, 247.83037927050182, 1.6880738242455653, 0.010461557679095622, 0.2835550558990694, 0.3011835613016052],
the coordinate of class 3 is [4.40755858558562, 0.2008179835886847, 236.6460828025471, 18.703058472485537, 36.7814311126413, 2.647214093073966, 17.63358581511448],
the coordinate of class 4 is [1.0757908165680417, 0.262256000000000193, 240.75309585798934, 4.6781585798817735, 0.07010650887573965, 0.44911242603550294, 11.069656804733727],
the coordinate of class 5 is [0.40684176723468735, 0.10702522401201667, 233.99229787123772, 1.846667011964682, 0.03970862671569897, 0.36678406795462787, 0.11809188377272492],
the coordinate of class 6 is [0.3288506824866082, 0.10052731203338121, 237.1437926397056, 1.4819260450978666, 0.027525703225157738, 0.3310122923003444, 0.19367285898249114],
the coordinate of class 7 is [1.3429974244675547, 0.15068489351163836, 238.47786181277894, 5.731107809146446, 0.15839524517087666, 0.5061746739309889, 0.34860491992735676],
the coordinate of class 8 is [0.3690865892359043, 0.09712571753302077, 245.6925162023606, 1.5872015733047022, 0.018606373672683623, 0.3157017616672945, 0.32333283501625624],
the coordinate of class 9 is [1.1958043802351446, 0.14101507723046106, 242.80408545300966, 5.031608391608383, 0.12627372627372627, 0.34159686467378775, 0.37943594866671787],
the coordinate of class 10 is [5.945717127607947, 0.17604172731683687, 235.47479864143642, 25.31639980591946, 3.3114992721979624, 69.06817079087821, 12.038088306647259],
the coordinate of class 11 is [0.34686049222197585, 0.11547972213445233, 239.6332511409352, 1.558144040467892, 0.023492175318452366, 0.35487948280952947, 0.4305362817788783],
the coordinate of class 13 is [0.47279835776612166, 0.21396640488655239, 241.62938645287758, 2.177196771378819, 0.038110820244328094, 1.7883398778359512, 0.5229930191972076],
the coordinate of class 14 is [3.30398683457359, 0.1967017744705212, 238.06517029192833, 14.000000000000005, 37.02752337340202, 2.177447052089296, 0.39815874833047127],
the coordinate of class 15 is [0.33388335680888737, 0.0972409741360347, 243.1593463571684, 1.4605834200914707, 0.015624553452956907, 0.23006511931736992, 0.42477391961132543],
the coordinate of class 16 is [2.7145957262176026, 0.1770184401778946, 236.4914773836647, 11.61247423798682, 0.4662653216183968, 0.5414904002603319, 0.26049463065408396],
the coordinate of class 17 is [3.8969452908867646, 0.19522018761726045, 237.6147493433398, 16.523069418386413, 0.6527579737335835, 31.605853658536585, 17.617448405253285],
the coordinate of class 18 is [1.83638745130194, 0.12328784744719777, 239.76812465042048, 7.657364445355285, 0.2060299364363338, 0.433304088037728113, 18.250700028504407],
the coordinate of class 19 is [2.680934950385874, 0.18926360629447714, 238.74185025558737, 11.449263305602841, 0.39460759747419066, 30.5647489225218, 0.38288062543850861],
the number of each class: Counter({17: 609626, 11: 247329, 14: 244870, 10: 193525, 7: 156592, 12: 91007, 5: 79673, 8: 65167, 1: 63991, 6: 60395, 3: 42250, 4: 38747, 2: 34854, 0: 313
the Loss: 14.85667284418026
Since the value of loss has no further changes at the 29 time, loop out!!!

```

K=20

```
this is the time of 50:

the coordinate of class 1 is [0.9712139135333028, 0.2545780406515505, 242.35599305261903, 4.242435337745919, 0.03431441580997981, 0.39243299065859266, 10.532460216870863],  
the coordinate of class 2 is [3.4793376935834326, 0.17772152017804986, 236.52604984780227, 14.757104482492794, 0.2720328887435472, 0.8109364415687557, 17.30746778689776],  
the coordinate of class 3 is [1.4112978453247604, 0.15082259549679633, 241.28467708948938, 5.962832578922569, 0.21479873220187842, 0.46511132094148453, 0.35889930309873896],  
the coordinate of class 4 is [0.387997876880456826, 0.09899336501434555, 244.70260421934705, 1.6693794160214879, 0.02096655466477048, 0.31825397222820345, 0.3408179309861341],  
the coordinate of class 5 is [0.41683427154161445, 0.10376660907368225, 235.0063231523785, 1.873021402296195, 0.03813677404971575, 0.33526084048601046, 0.11379723553672946],  
the coordinate of class 6 is [0.33161663734073565, 0.11169965315139438, 240.81945029559319, 1.482394268136449, 0.019437446991657913, 0.39374596503664694, 0.4524887021026115],  
the coordinate of class 7 is [0.352412802169234975, 0.10936774686389894, 242.6725873595889, 1.552963124301347, 0.019684716250939097, 0.37210616362683635, 0.4431933685612733],  
the coordinate of class 8 is [1.5999929818247236, 0.11122786575498418, 233.76355407594065, 6.82521594385471, 0.13019614900125967, 0.4439445744106532, 16.88644952312399],  
the coordinate of class 9 is [1.6056678811727478, 0.10207041706137887, 244.4851683305374, 6.533899293157296, 0.10544341616264666, 0.3489883164516991, 18.676917097816318],  
the coordinate of class 10 is [1.1538494964028727, 0.26804422062350314, 239.21824076738517, 5.005371702637947, 0.0637886882494085, 0.5103597122302158, 11.43913669847482],  
the coordinate of class 11 is [0.3962261817864315, 0.1179885705016624, 238.63751283635023, 1.771468678058638, 0.03431968905775266, 0.42183084092908346, 0.3585443610523623],  
the coordinate of class 12 is [1.567248168027009, 0.10420105395992724, 241.14852516018664, 6.214927668885691, 0.09340489717662223, 0.36428234860835046, 18.22501448788704],  
  
the coordinate of class 14 is [1.5171818535594086, 0.11077898041698762, 238.30628338312923, 6.34084729999832, 0.11548634333920361, 0.41904611142990944, 17.750743679548318],  
the coordinate of class 15 is [2.524413524116701, 0.15653304967459378, 239.72467327774618, 10.56817074268978, 0.28413913003694424, 0.9108762538745725, 17.93928787930778],  
the coordinate of class 16 is [3.729320694893975, 0.18965528326397765, 237.71570359116868, 15.845168108857788, 0.8480304731708391, 36.11502300900544, 10.687782108021226],  
the coordinate of class 17 is [2.332684045239663, 0.26833044102686904, 239.01344683142875, 9.806319190952844, 0.18466878104242715, 0.5362336185745916, 28.402489378253843],  
the coordinate of class 18 is [2.277391381743182, 0.1720665147074782, 237.82927385216394, 9.706423531965804, 0.2651687832410724, 1.9889721046347553, 0.22824270053185716],  
the coordinate of class 19 is [3.005479485912018, 0.24648418190805665, 238.19234923381129, 13.447478991596622, 0.022244191794364, 8.7245427582797825, 12.878892733564014],  
the coordinate of class 20 is [4.060993511569694, 0.19502646185115685, 237.1260653142583, 17.166174171357394, 38.061014696685426, 2.5994566916823016, 11.064083020637899],  
the number of each class: Counter({6: 317156, 5: 315602, 3: 200568, 11: 184610, 10: 159402, 13: 151595, 2: 103088, 14: 88300, 8: 82527, 12: 79032, 4: 71462, 19: 51128, 17: 46118, 15:  
the loss: 16.02399140920946}
```

Additional Requirements

- Explain the stopping criteria you selected for your algorithm (see Resources) and how they may impact your results.

There are two stopping criterias in my program. The first one is The Maximum Number of Iterations, and the second one is Convergence.

For The Maximum Number of Iterations, I set it to be 50. When the iteration time equals to 50, the loop will end even though it doesn't converge enough.

For the Convergence, I choose the metric of LOSS to see if it is converged. If the difference between loss of this time and loss of last time is less than 0.0000001, the loop will end even though the iteration time doesn't equal to the maximum number of iterations.

- Explain the centroid initialization method you selected and how that may impact your results.

I choose the way of random initialization to select the nodes. There are two main steps: the first step is choosing k samples from all nodes randomly; and the second step is setting these k samples to be the centroid of each class. I tried to run my program multiple times with different initialization, but the result doesn't change. So we can conclude that if the iteration time is large enough, the initialization will not impact the result.

- Explain why your algorithm may require different amounts of time to run on the same input and parameters.

Because the way I choose to initialize the centroids of each class. Since I choose the way of random initialization to select the nodes, which may be closed to each other and increase the time to calculation and to get convergence.

- Explain why your algorithm may produce different results on the same input and parameters.

Because the result doesn't converge enough for two reasons.

The first reason is that I set the maximum number of iterations is 50, but in some situations, 50 is not large enough. After consideration, I have to make a balance between the precision and the resource it costs. 50 iteration times can work well in most situations, so I choose this number.

The second reason is the way of initialization. Due to some bad initialization situations, the result will not converge enough.