

Requirements for Test Case Dataset

For K = 2

Loss in iteration 0: 90.05280176706488

Loss in iteration 1: 59.152535564150696

Loss in iteration 2: 34.39213437260416

Loss in iteration 3: 30.96376193434194

Coordinates of centroids are:

0.06026253328707723 -0.08038639294559319

10.168086243285888 10.046715814097372

Number of points in cluster 0 = 100

Number of points in cluster 1 = 100

Requirements for Electric Power Consumption Dataset

For K = 2

Loss in iteration 0: 521.9170177420248

Loss in iteration 1: 137.40402465320855

Coordinates of centroids are:

0.9527106088171133 0.12032132390788913 241.01129455097455

4.0395499800903245 0.13569043930052566 0.5229245057811579

6.217596864234928

4.013145025857196 0.19508150648848038 237.23409026889172

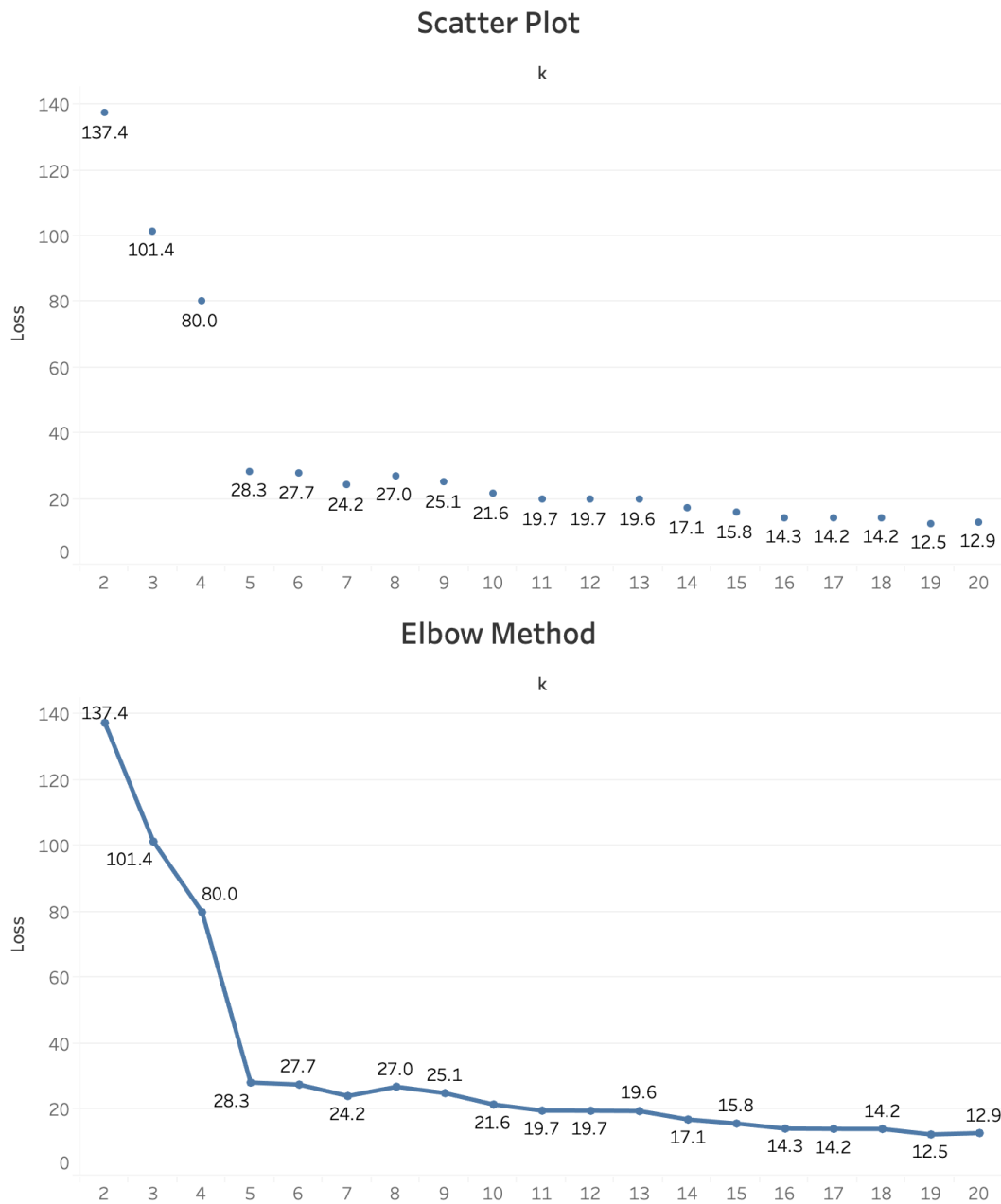
16.999367816709732 21.865026717270002 17.611357796389676

11.52417455999828

Number of points in cluster 0 = 1956269

Number of points in cluster 1 = 93011

For K from 3 to 20



The scatter plot and elbow method is shown above. Using the elbow method, it is clearly seen that elbow is made at $k = 5$ where loss is approximately 28.3. Hence, there the optimal number of clusters for this data set is 5

K = 3

Loss in iteration 0: 521.2897957109951

Loss in iteration 1: 105.9195836937821

Loss in iteration 2: 101.51374916186732

Loss in iteration 3: 101.42226220983983

Loss in iteration 4: 101.3864884088504

Loss in iteration 5: 101.38277876005351

Loss in iteration 6: 101.3826686756888

Coordinates of centroids are:

0.9428056036733757 0.1197849315103553 241.02286624905292
3.9953876191339663 0.09746543363901787 0.4206752498424417
6.208893233353484

3.9830617275218714 0.20015652020157415 237.18984351516195
16.90229687914436 36.595561842454245 2.4191848642913976
11.277181504729908

3.657305795918358 0.19136293877551125 237.7930989795942
15.545518367346823 0.8168775510204082 34.827285714285715
10.796020408163265

Number of points in cluster 0 = 1943725

Number of points in cluster 1 = 56555

Number of points in cluster 2 = 49000

K = 4

Loss in iteration 0: 521.2841543669854

Loss in iteration 1: 80.00236472449552

Coordinates of centroids are:

0.945390610575488 0.11991805047958853 241.02001614773434
4.006448015494286 0.09204841967552492 0.4668336723764889
6.210641813314384

3.2379398690311048 0.1982506572343583 238.109908226184 13.737957076621598
36.68142058219014 1.1884231155298504 0.5221547727164093

3.8964520205287383 0.1923543796092651 237.5080150515403
16.550183292362043 2.418186915081727 36.34780264803554 11.194764307586148

4.28890959909163 0.20091437389000502 236.78539202841492
18.212775497132505 36.11101406236352 1.203947943051795 17.73124290331033

Number of points in cluster 0 = 1947638

Number of points in cluster 1 = 20921

Number of points in cluster 2 = 46374

Number of points in cluster 3 = 34347

K = 5

Loss in iteration 0: 443.5460553526384

Loss in iteration 1: 103.74420802199694

Loss in iteration 2: 97.85376953343179

Loss in iteration 3: 72.91350597677392

Loss in iteration 4: 28.442477990183665

Loss in iteration 5: 28.274597260721247

Coordinates of centroids are:

1.799321471706563 0.13181729388107927 239.81645131947752
7.511944102083346 0.19889229704725808 0.47478786530875755
17.87963537853725

3.2928078627321447 0.19746874705383297 238.06899453191213
13.965475629301404 36.80239464504572 2.1605072122183464
0.3976619213726784

3.6903601692212717 0.19095809859903626 237.74281574863664
15.68610727268852 0.7948510810178788 35.52328918556942 10.581985161249177

4.408320518333769 0.2009019810211868 236.646120810756 18.706613915885736
36.77394570109802 2.6671827069178065 17.63429947535908

0.5196155172942838 0.1139612098438665 241.6201623032932
2.2586152092909075 0.05354051806449626 0.4187136169033172
0.4138101764868944

Number of points in cluster 0 = 647466

Number of points in cluster 1 = 21214

Number of points in cluster 2 = 47039

Number of points in cluster 3 = 34881

Number of points in cluster 4 = 1298680

K = 6

Loss in iteration 0: 433.39703656217074

Loss in iteration 1: 78.19231557860796

Loss in iteration 2: 28.154653985531088

Loss in iteration 3: 27.73569627133258

Loss in iteration 4: 27.672578242191154

Loss in iteration 5: 27.662308272138976

Loss in iteration 6: 27.65812715162177

Loss in iteration 7: 27.656536754068906

Loss in iteration 8: 27.655926232941262

Coordinates of centroids are:

2.984314479928186 0.2507241246633315 238.17775426446124
13.359548544311867 17.456714120815697 0.7060407849172758
14.013851481338977

3.3301459366560104 0.19572266142892242 238.05289761846248
14.081198134053485 37.490351092560765 2.2198379572796463
0.3920451755462804

3.6898829511126103 0.19082678806960954 237.74422882185524
15.683610602901664 0.78407011870825 35.53286814449219 10.578011317704123

4.478690432681878 0.19668869823768106 236.5830132870804
18.960838727661592 37.910397373555924 2.824821135441509
17.621798246972467

1.7932071620544452 0.13119266653314823 239.82346271551418
7.482050302687843 0.1280546407871304 0.47450474411585236
17.878893458849394

0.5185479224263763 0.11386372406695902 241.62203971603572
2.253366097381327 0.043297548706852707 0.4186015330984678
0.41350661599489585

Number of points in cluster 0 = 7797

Number of points in cluster 1 = 20365

Number of points in cluster 2 = 47006

Number of points in cluster 3 = 32287

Number of points in cluster 4 = 644061

Number of points in cluster 5 = 1297764

K = 7

Loss in iteration 0: 433.39303068480746

Loss in iteration 1: 76.93945377400556

Loss in iteration 2: 27.962602904268312

Loss in iteration 3: 27.567058615439212

Loss in iteration 4: 27.520186096885652

Loss in iteration 5: 27.51471890042866

Loss in iteration 6: 27.509155883539215

Loss in iteration 7: 27.498250476879885

Loss in iteration 8: 27.471467590297266

Loss in iteration 9: 27.3499812133534

Loss in iteration 10: 26.804888801179647

Loss in iteration 11: 25.795712255553997

Loss in iteration 12: 25.33052087341148

Loss in iteration 13: 25.140907952194656

Loss in iteration 14: 24.988522563163226

Loss in iteration 15: 24.74425461799536

Loss in iteration 16: 24.503366002973433

Loss in iteration 17: 24.37168920913414

Loss in iteration 18: 24.30349832477463

Loss in iteration 19: 24.263174529115577

Loss in iteration 20: 24.237463491283496

Loss in iteration 21: 24.220344635231367

Loss in iteration 22: 24.20885527081405

Loss in iteration 23: 24.201351926352363

Loss in iteration 24: 24.19649248574719

Loss in iteration 25: 24.19330686434079

Loss in iteration 26: 24.19124231387426

Loss in iteration 27: 24.18996199275832

Loss in iteration 28: 24.189137863367552

Loss in iteration 29: 24.188618127832413

Loss in iteration 30: 24.18828010807663

Loss in iteration 31: 24.188066064093217

Coordinates of centroids are:

2.9952016653656055 0.2508108248763981 238.1874707259958 13.39955763726251
17.559979182930004 0.7098620869112673 14.234452250845694

3.3301459366560104 0.19572266142892242 238.05289761846248
14.081198134053485 37.490351092560765 2.2198379572796463
0.3920451755462804

3.694952816089492 0.1906964857594276 237.74565032666078 15.70415474614618
0.7856868354754686 35.59193389982493 10.606409325761135

4.478982060418274 0.19666020139426835 236.58331247095168
18.961840433772576 37.91429899302866 2.825499612703331 17.621905499612705

1.7934174942175474 0.1311599010200988 239.82354229094796
7.482779017873614 0.12807739446103947 0.47509114322417895
17.883324246194665

0.40082730607137496 0.10496914241679667 243.40755618571296
1.739801837578053 0.02425972397276746 0.3557555619071842
0.4266284057985613

0.7055077238610066 0.12799777448072128 238.8056728129724
3.0692445929010495 0.07631626969644076 0.5231200114251258
0.3981457972992272

Number of points in cluster 0 = 7686

Number of points in cluster 1 = 20365

Number of points in cluster 2 = 46838

Number of points in cluster 3 = 32275

Number of points in cluster 4 = 643767

Number of points in cluster 5 = 794197

Number of points in cluster 6 = 504152

K = 8

Loss in iteration 0: 433.3930139522183

Loss in iteration 1: 76.85086088253175

Loss in iteration 2: 27.7775718620133

Loss in iteration 3: 27.277220590984435

Loss in iteration 4: 27.201738501810148

Loss in iteration 5: 26.998367033861083

Coordinates of centroids are:

3.6564237867395772 0.244285714285714 237.36989063567964
16.000729095465914 26.15607199817726 0.8332194121667806
17.840510366826155

3.3466996053354467 0.1952435429884599 238.03675425887985
14.13424589099266 37.726132787130936 2.245091672078733 0.3930658939901084

3.6891766739213847 0.19057069090598877 237.7480437844095
15.67982759356452 0.7776853155805915 35.58438953612427 10.577668245636495

4.513403432629721 0.19414184257249975 236.55300059183142
19.081429604787605 38.370388636811995 2.949727099362136
17.598967580719407

1.7582700148881494 0.13024914935741672 239.87343953908717
7.330975036275253 0.1190553381953472 0.471204056644455 17.88213445975933

0.5053298350822714 0.11342385728625998 241.6444500864565
2.1960533163191416 0.03368899228071914 0.41720281388231506
0.4144079819594335

2.9501584572490813 0.2124958178438656 237.50105715613444
12.998257434944222 5.994888475836431 0.8044842007434945
0.3076208178438662

3.9664763689699964 0.21626499348109543 236.8018864080829
17.06597131681875 4.479546936114732 0.8111962190352021 17.754807692307693

Number of points in cluster 0 = 4389

Number of points in cluster 1 = 20017

Number of points in cluster 2 = 46866

Number of points in cluster 3 = 30414

Number of points in cluster 4 = 635402

Number of points in cluster 5 = 1291312

Number of points in cluster 6 = 8608

Number of points in cluster 7 = 12272

K = 9

Loss in iteration 0: 433.3751298764944

Loss in iteration 1: 76.66876617195386

Loss in iteration 2: 27.3509721380068

Loss in iteration 3: 25.97519897330426

Loss in iteration 4: 25.361363994211732

Loss in iteration 5: 25.197365772224476

Loss in iteration 6: 25.141806446886488

Loss in iteration 7: 25.11332231153606

Loss in iteration 8: 25.094362142556303

Loss in iteration 9: 25.081040446518493

Loss in iteration 10: 25.072444784399615

Loss in iteration 11: 25.067587305179373

Loss in iteration 12: 25.064932933400947

Loss in iteration 13: 25.06352742643589

Loss in iteration 14: 25.06279751181467

Loss in iteration 15: 25.06240838917135

Loss in iteration 16: 25.062207267835316

Coordinates of centroids are:

3.7512966123609996 0.24388828549262992 237.19769071631683

16.37858805275406 27.123092836824412 0.860615464184122 17.840186190845618

3.368831047891916 0.1940508595988541 238.02076238231732

14.209823986901355 37.99887433483422 2.2813651248465003

0.39249897666803113

3.693656072839706 0.19043454732863926 237.74682356983564

15.698724445971363 0.7790757601786634 35.690259405600415 10.5256828723587

4.513706246297651 0.19408918580925444 236.5515401829777
19.082544592904963 38.373329822944775 2.9527084841703415
17.599914434278944

1.5182279754200445 0.11987804448311606 240.94266200446913
6.283493392787661 0.09947033552667356 0.39110337701887 17.741893523301975

0.5173274650275368 0.11374828918222642 241.6237307938272
2.2472847516630123 0.035281567596586384 0.4189521279549788
0.4115342132706393

2.9589867256637232 0.2518893805309733 238.5399955752213
13.160044247787635 13.799115044247788 0.6597345132743363
18.035176991150443

2.0779783290561684 0.24072996863416038 238.9964585115485
9.861248930710035 17.704875962360994 0.7082976903336184
0.47362418021100655

2.480668128441262 0.15950039792752563 237.03309316917628
10.47805334935845 0.1806915818025305 0.7197994661815741
18.193403606793463

Number of points in cluster 0 = 3867

Number of points in cluster 1 = 19544

Number of points in cluster 2 = 46568

Number of points in cluster 3 = 30386

Number of points in cluster 4 = 459725

Number of points in cluster 5 = 1296456

Number of points in cluster 6 = 4520

Number of points in cluster 7 = 3507

Number of points in cluster 8 = 184707

K = 10

Loss in iteration 0: 432.25411082209

Loss in iteration 1: 65.27592748801153

Loss in iteration 2: 23.624371346666226

Loss in iteration 3: 22.336423783932993

Loss in iteration 4: 21.966645077923474

Loss in iteration 5: 21.778728990379864

Loss in iteration 6: 21.641443054165872

Loss in iteration 7: 21.622319744441832

Loss in iteration 8: 21.612340740570875

Loss in iteration 9: 21.607150901430384

Loss in iteration 10: 21.60459494585259

Loss in iteration 11: 21.60334309378318

Loss in iteration 12: 21.60273607964587

Loss in iteration 13: 21.602440970284736

Coordinates of centroids are:

3.750716094032547 0.2440532162231981 237.19281064324392
16.377421854817864 27.098424179798503 0.8602428313097391
17.839059674502714

3.369431453884345 0.19402611768320815 238.0198094945465 14.21173759410048
38.00752803810109 2.2829415680852154 0.39227735955343884

3.698488407171166 0.19029662989139945 237.74823629546847
15.71834166522999 0.7807490087915877 35.7473064988795 10.555270642992587

4.513547102760699 0.19409377776315373 236.55210621565467
19.08187292290515 38.3725774077852 2.952354315422329 17.599782830443225

1.5185369820328107 0.11986259930673103 240.94473175488017
6.284583330611842 0.09949930477129261 0.39103405206272945
17.74489784816379

0.40127229015233523 0.10482029750387185 243.43899592761954
1.7410040341444122 0.022406534218813175 0.35546395223816635
0.4229858288364239

2.9578670212766016 0.25183111702127653 238.54372340425542
13.155097517730521 13.78590425531915 0.6595744680851063
18.035682624113477

2.0845384392225075 0.24023324630113158 239.0388540760083
9.888018566869768 17.982593559617058 0.7072816942268639
0.47432550043516103

2.4788342498631963 0.159486262887852 237.03248530391284
10.470166275673868 0.1807469131454763 0.7214814734549474
18.205707226950853

0.6967038502104062 0.1274857846931357 238.84390150371922
3.0299189172859977 0.05616133101204251 0.5214092288856439
0.3975684933509835

Number of points in cluster 0 = 3871

Number of points in cluster 1 = 19527

Number of points in cluster 2 = 46408

Number of points in cluster 3 = 30391

Number of points in cluster 4 = 459561

Number of points in cluster 5 = 784057

Number of points in cluster 6 = 4512

Number of points in cluster 7 = 3447

Number of points in cluster 8 = 184573

Number of points in cluster 9 = 512933

K = 11

Loss in iteration 0: 432.2492251745798

Loss in iteration 1: 65.07602215737566

Loss in iteration 2: 23.548692361163507

Loss in iteration 3: 22.286539479738614

Loss in iteration 4: 21.929575692254218

Loss in iteration 5: 21.569950324352273

Loss in iteration 6: 20.24494739178202

Loss in iteration 7: 19.769870356568653

Loss in iteration 8: 19.753929332888703

Loss in iteration 9: 19.749648538432094

Loss in iteration 10: 19.747725235373306

Loss in iteration 11: 19.74681324383093

Loss in iteration 12: 19.746390661020357

Coordinates of centroids are:

3.7422408488063637 0.24510397877984078 237.20609018567563
16.34795755968169 26.883023872679043 0.773474801061008 17.839522546419097

3.2701895361380515 0.19120161812297704 238.13962243797238
13.783991370010817 38.03079827400216 0.6571736785329019
0.39298813376483277

3.643348179460914 0.18984760203081216 237.8136308369487
15.477868084457196 0.3050574161636851 35.40420107641688
10.509990630379361

4.367468553236659 0.19090442164839033 236.70652069331376
18.443565617262223 38.42235585426247 0.6109656880084896
17.626317651220376

1.5190184477292141 0.11992502185286281 240.94418685611168
6.286637790445848 0.09951423588913967 0.3913793178428073
17.74796366119149

0.401268590674316 0.10483363269800904 243.4377635992364
1.7410062477759995 0.022410920415736595 0.3553826365083837
0.4230972707884233

2.955086045474817 0.2518408381631743 238.5517855550604 13.142978154257715
13.739188586714222 0.6627284886312974 18.038118591172537

2.0828165404775727 0.2410186371578336 239.0309784507865 9.882644146767646
17.926033779848574 0.7108328479906815 0.47408270238788586

2.4790637646049154 0.1593608873486521 237.0250751497788
10.471248621665275 0.18067996023878458 0.7077822258676039
18.199561105709428

0.6966823779648442 0.12746463982204126 238.84227625841714
3.0297957869476497 0.056098584265935544 0.5180942716921486
0.3973987959918432

6.109036999999986 0.23581550000000023 234.85472499999943
26.121300000000087 35.9865 35.96725 12.3005

Number of points in cluster 0 = 3770

Number of points in cluster 1 = 18540

Number of points in cluster 2 = 45893

Number of points in cluster 3 = 28270

Number of points in cluster 4 = 459894

Number of points in cluster 5 = 784439

Number of points in cluster 6 = 4486

Number of points in cluster 7 = 3434

Number of points in cluster 8 = 184099

Number of points in cluster 9 = 512455

Number of points in cluster 10 = 4000

K = 12

Loss in iteration 0: 432.246103107571

Loss in iteration 1: 64.57432219538778

Loss in iteration 2: 23.292802276559776

Loss in iteration 3: 21.562390446338274

Loss in iteration 4: 20.53800996232314

Loss in iteration 5: 19.940035957766785

Loss in iteration 6: 19.75965633279739

Loss in iteration 7: 19.741020993875377

Loss in iteration 8: 19.73194132760325

Loss in iteration 9: 19.726006996778406

Loss in iteration 10: 19.72068049790593

Loss in iteration 11: 19.71590216837842

Loss in iteration 12: 19.71258763515408

Loss in iteration 13: 19.7108370739823

Loss in iteration 14: 19.71017252817945

Coordinates of centroids are:

3.8696073280331813 0.23501348081576204 237.1281956446592
16.799792602834422 30.014517801590046 0.6961631524369167
17.78949187694435

3.270131520742271 0.191205588822355 238.13949182715695 13.78365431299566
38.03182823542105 0.6572800345255435 0.39170308032583484

3.643272576744585 0.18984675047386793 237.81349136146943
15.47754417307554 0.30503932547550056 35.40201311575416
10.510468637660951

4.37190110483321 0.1902561629538991 236.71028790441483 18.457264188289596
38.51031057688847 0.6115809551228992 17.628027494871702

1.5183034444800716 0.11985581276495516 240.95909981807802
6.283138406028221 0.09841590169985345 0.39125458925486445
17.745681568504114

0.4013087785499078 0.10482092360638617 243.4412172757772
1.7411451126158282 0.02240210170495453 0.3553545988837884
0.42287621080366217

2.7722426926483714 0.24830941836433446 238.92139946855633
12.342958370239199 11.697962798937112 0.566873339238264
18.074992618836728

2.0829181950509414 0.24102998544395937 239.03036390101914
9.882969432314438 17.927510917030567 0.7106259097525474
0.47627365356622997

2.470451297828167 0.1589904908404394 237.02898341275133 10.43411357206603
0.17527941223927798 0.7043823886922754 18.199977410367566

0.6959937140352922 0.127436506499205 238.84657779077332
3.0268462100194866 0.056042062217029356 0.5177586290832968
0.3977274718854973

3.471996246246246 0.2612252252252251 237.40001876876912
15.333858858858843 20.305555555555557 0.8761261261261262 17.8993993993994

6.109036999999986 0.23581550000000023 234.85472499999943
26.121300000000087 35.9865 35.96725 12.3005

Number of points in cluster 0 = 2893

Number of points in cluster 1 = 18537

Number of points in cluster 2 = 45899

Number of points in cluster 3 = 27787

Number of points in cluster 4 = 457863

Number of points in cluster 5 = 783364

Number of points in cluster 6 = 3387

Number of points in cluster 7 = 3435

Number of points in cluster 8 = 185926

Number of points in cluster 9 = 513525

Number of points in cluster 10 = 2664

Number of points in cluster 11 = 4000

K = 13

Loss in iteration 0: 432.2450061142449

Loss in iteration 1: 64.61690256289633

Loss in iteration 2: 23.23044628540317

Loss in iteration 3: 21.393629559525767
Loss in iteration 4: 20.368620234294987
Loss in iteration 5: 19.853940521592378
Loss in iteration 6: 19.68655347462226
Loss in iteration 7: 19.66586913712233
Loss in iteration 8: 19.654117236310697
Loss in iteration 9: 19.645682164183032
Loss in iteration 10: 19.64020074055361
Loss in iteration 11: 19.636672685376638
Loss in iteration 12: 19.634331339039175
Loss in iteration 13: 19.632181890483203
Loss in iteration 14: 19.628706097488152
Loss in iteration 15: 19.62546820143779
Loss in iteration 16: 19.623422485766245
Loss in iteration 17: 19.622306037028903
Loss in iteration 18: 19.621712235579494
Loss in iteration 19: 19.621364218430475
Loss in iteration 20: 19.62114869397642
Loss in iteration 21: 19.621027650822587
Loss in iteration 22: 19.62096960065532
Loss in iteration 23: 19.620945096075427
Loss in iteration 24: 19.620930615771034
Loss in iteration 25: 19.62092086293297
Loss in iteration 26: 19.62091420057035
Loss in iteration 27: 19.6209124833284

Loss in iteration 28: 19.620911179872262

Loss in iteration 29: 19.62091060042396

Loss in iteration 30: 19.620910420818724

Coordinates of centroids are:

3.876912516823685 0.23668438761776567 236.99937752355265

16.842799461641988 29.811911170928667 0.7301480484522207 17.79172274562584

2.917266218268603 0.17031807333477933 238.91811600491826

12.25402473421568 37.35387285745281 0.47103493165545673

0.41997541042887104

3.643199381357957 0.18985718953536632 237.8132696538672

15.477282331670423 0.30498616768684517 35.39919837933213 10.5121876837955

4.370951462598511 0.19019515705393414 236.71931925304844

18.452797466988198 38.50516317058252 0.6106933400496528 17.63238945058108

1.5178389328062882 0.11982537988581599 240.97956589812284

6.280620553358191 0.09795125164690383 0.39078173034694774

17.746381203337727

0.4013558833385383 0.10479705506907355 243.4461476200616

1.7412717537831297 0.022377330785425763 0.3552975244877964

0.4225970750225756

2.759704594511258 0.24969781066913357 238.90237126117782

12.27912426765344 11.27690410114092 0.5624421831637373 18.090348442799876

2.066767115097155 0.2413626307922274 239.0071509715995 9.829237668161461

17.4863976083707 0.7070254110612855 0.470254110612855

2.4590078219172944 0.1585242224546884 237.03049873351432

10.385268456910136 0.17330883563353283 0.7007333379355024

18.19219188920809

0.6950020600461178 0.12739527063105194 238.8528263406461

3.022573912166035 0.05547950923914204 0.5173550638109495

0.39813838617419717

3.408071916576771 0.25804746494066866 237.60370010787528

15.068967997123332 19.855807263574253 0.8399856166846458 17.893563466379

6.113288008028085 0.23563020572002036 234.85050175614595
26.139387857501337 35.97992975413949 36.02257902659308 12.338936276969394

4.262690976514236 0.25227729707457774 235.94313967861572
18.108075813761808 39.73135558302431 1.2435105067985166
0.33106716110424395

Number of points in cluster 0 = 2972

Number of points in cluster 1 = 13827

Number of points in cluster 2 = 45907

Number of points in cluster 3 = 27793

Number of points in cluster 4 = 455400

Number of points in cluster 5 = 781818

Number of points in cluster 6 = 3243

Number of points in cluster 7 = 3345

Number of points in cluster 8 = 188317

Number of points in cluster 9 = 515037

Number of points in cluster 10 = 2781

Number of points in cluster 11 = 3986

Number of points in cluster 12 = 4854

K = 14

Loss in iteration 0: 432.24324287070755

Loss in iteration 1: 60.90310928732821

Loss in iteration 2: 20.461085202212182

Loss in iteration 3: 19.33536170984698

Loss in iteration 4: 18.551332289627236

Loss in iteration 5: 17.499615164828693

Loss in iteration 6: 17.136946129551117

Loss in iteration 7: 17.10686135120449
Loss in iteration 8: 17.0957340636945
Loss in iteration 9: 17.087403362516877
Loss in iteration 10: 17.08158923081499
Loss in iteration 11: 17.077947243667115
Loss in iteration 12: 17.075645189839165
Loss in iteration 13: 17.073733220570446
Loss in iteration 14: 17.070773843737467
Loss in iteration 15: 17.06722070052192
Loss in iteration 16: 17.06470041971895
Loss in iteration 17: 17.063386485822427
Loss in iteration 18: 17.06266730714549
Loss in iteration 19: 17.06225224384823
Loss in iteration 20: 17.06199447105399
Loss in iteration 21: 17.06184694486254
Loss in iteration 22: 17.061760509751426
Loss in iteration 23: 17.0617271961533
Loss in iteration 24: 17.06171133971974
Loss in iteration 25: 17.061698489978554
Loss in iteration 26: 17.061690180122586
Loss in iteration 27: 17.061684619269013
Loss in iteration 28: 17.061683156408
Loss in iteration 29: 17.06168266064841
Coordinates of centroids are:

3.874479110512127 0.2364487870619945 237.0012668463607 16.83241239892183
29.81266846361186 0.7075471698113207 17.79380053908356

2.91626204797449 0.17023682875570645 238.92404377128813 12.24943836509894
37.35219943474165 0.4738749184723531 0.41945068483223424

5.903715481171542 0.175721880383953 235.5277775043075 25.130199360078738
2.5973418656165395 69.18631553039626 11.990647304947084

4.36823742875696 0.19003073371329637 236.72223108000756
18.440819565688006 38.506493038020345 0.5662289878075175
17.631989033980233

1.517813791019862 0.11993989886850165 240.99672328208644
6.280109114403325 0.09783248689546584 0.39050298917897364
17.747319000857832

0.4017018429932091 0.1048382737805594 243.45486543033022
1.7426689068199939 0.022406249157695995 0.35374842930357986
0.42249712172688686

2.758880172946268 0.24934527486102528 238.90141445336621
12.275972822730111 11.280111179740581 0.5348980852378011
18.090487955528104

2.0635512282804025 0.24099221090473355 239.01355901737577
9.816297183942508 17.488016776512882 0.6659676452965848
0.47094068304373876

2.445971194090655 0.1574835466614434 237.0166998079209 10.329674213842882
0.1723433638994862 0.5828328632883395 18.18820142971284

0.6904273844384566 0.12704841553556145 238.86197935639512
3.0028815130658213 0.05505029293189309 0.48113023130684207
0.3982673760773255

3.406359899026325 0.25807356653443914 237.61030652722724
15.059718716191844 19.86080057699243 0.7811034980165885 17.89542012261089

5.932637688703789 0.24104060385216047 235.01536959916663
25.356220718375937 36.158771473191045 32.87532535137949
12.118427902134306

4.256888521199605 0.25177621509824205 235.92986556359878
18.082854188210913 39.75387797311272 1.047569803516029 0.3311271975180972

3.4036369607269643 0.1922451752215586 238.07181767061292
14.460074677223382 0.2981915515767691 31.640447163615097
10.368122722569616

Number of points in cluster 0 = 2968

Number of points in cluster 1 = 13799

Number of points in cluster 2 = 4063

Number of points in cluster 3 = 27722

Number of points in cluster 4 = 453469

Number of points in cluster 5 = 779113

Number of points in cluster 6 = 3238

Number of points in cluster 7 = 3338

Number of points in cluster 8 = 188989

Number of points in cluster 9 = 516673

Number of points in cluster 10 = 2773

Number of points in cluster 11 = 3842

Number of points in cluster 12 = 4835

Number of points in cluster 13 = 44458

K = 15

Loss in iteration 0: 432.23872420036065

Loss in iteration 1: 59.77379881992515

Loss in iteration 2: 20.4429762429872

Loss in iteration 3: 19.31186777473433

Loss in iteration 4: 18.48737944215903

Loss in iteration 5: 17.353047644958078

Loss in iteration 6: 17.103489494348604

Loss in iteration 7: 17.07868967926566

Loss in iteration 8: 17.069636457024234
Loss in iteration 9: 17.06503127381506
Loss in iteration 10: 17.062237626653914
Loss in iteration 11: 17.059855182947707
Loss in iteration 12: 17.0571924614092
Loss in iteration 13: 17.05336978897903
Loss in iteration 14: 17.050324597796415
Loss in iteration 15: 17.04849841835002
Loss in iteration 16: 17.047480044751147
Loss in iteration 17: 17.046919248933282
Loss in iteration 18: 17.046555938503296
Loss in iteration 19: 17.046339372909262
Loss in iteration 20: 17.046202477942842
Loss in iteration 21: 17.046090002988954
Loss in iteration 22: 17.04594728271967
Loss in iteration 23: 17.045716866174477
Loss in iteration 24: 17.04526656921531
Loss in iteration 25: 17.04360884410597
Loss in iteration 26: 17.032946818914464
Loss in iteration 27: 16.932296941515766
Loss in iteration 28: 16.716353578623153
Loss in iteration 29: 16.569255834428667
Loss in iteration 30: 16.422410749379733
Loss in iteration 31: 16.282755169122844
Loss in iteration 32: 16.148931735334607

Loss in iteration 33: 16.04080683856708
Loss in iteration 34: 15.97737288895949
Loss in iteration 35: 15.939389515040862
Loss in iteration 36: 15.912130878920115
Loss in iteration 37: 15.886769541136278
Loss in iteration 38: 15.862797732509074
Loss in iteration 39: 15.850191101578911
Loss in iteration 40: 15.845598617372968
Loss in iteration 41: 15.843818577486797
Loss in iteration 42: 15.842965401423822
Loss in iteration 43: 15.842491858717015
Loss in iteration 44: 15.842197965184763
Loss in iteration 45: 15.841992230786348
Loss in iteration 46: 15.841835746526991
Loss in iteration 47: 15.841719872177938
Loss in iteration 48: 15.84163445994252
Loss in iteration 49: 15.84156375039137
Loss in iteration 50: 15.841509420987185
Loss in iteration 51: 15.841462306409682
Loss in iteration 52: 15.841424466865208
Loss in iteration 53: 15.841394751290043

Coordinates of centroids are:

3.8739036388140136 0.23667789757412386 237.00174528301832
16.830323450134767 29.806603773584907 0.7075471698113207
17.79177897574124

2.9165884994206235 0.170198290845886 238.91968424102006 12.25101390498263
37.34957995365006 0.47421784472769407 0.41910486674391656

5.904115706548492 0.17576514032496335 235.52633924175316
25.13190546528801 2.5979812900049235 69.19079271294929 11.989167897587395

4.368203505987608 0.19001702496032324 236.72245924108964
18.440672341653546 38.50620401096523 0.5661881402395037
17.632051651998268

1.5857271818281127 0.11489899692966354 242.2704687472391
6.5225258010609775 0.10114439761015578 0.3820394232433903
18.356907900547995

0.4018951065029129 0.10486186278374914 243.45699710865412
1.7435035316866028 0.022414238243443033 0.3538045761011557
0.4233426629656413

2.742901644430661 0.24873037542662105 238.87640086875564
12.212038473471939 11.294135898231461 0.5349053676698728
18.053986968662738

2.0635512282804025 0.24099221090473355 239.01355901737577
9.816297183942508 17.488016776512882 0.6659676452965848
0.47094068304373876

1.4782447478424858 0.12804101269815735 237.85179243755238
6.213908618063077 0.10584846057093993 0.42346856177433884
16.882819083357894

0.6891283510552279 0.1268834919694785 238.86433995173576
2.996978267140268 0.05502418741325343 0.4810362549870207
0.3864507898898742

2.907268179417768 0.17562741728626377 238.0070302689877
12.257956193365548 0.19194112173818287 0.6611817564565747
18.69421695432408

5.9320983606557265 0.24108456934686456 235.0152797293776
25.353942232630846 36.15899037210512 32.871975019516 12.115534738485557

4.258537202072559 0.25200580310880843 235.93701761658028
18.089533678756418 39.766424870466324 1.0437305699481865
0.33181347150259066

3.4033097432892188 0.1921281074624183 238.0670835493276
14.458865424057278 0.29818116252338345 31.67058081092655
10.353242128513152

3.407551314368024 0.2581073100468129 237.6096435001805 15.065034209578677
19.84515664386028 0.780338494778538 17.902052574720923

Number of points in cluster 0 = 2968

Number of points in cluster 1 = 13808

Number of points in cluster 2 = 4062

Number of points in cluster 3 = 27724

Number of points in cluster 4 = 283031

Number of points in cluster 5 = 778523

Number of points in cluster 6 = 3223

Number of points in cluster 7 = 3338

Number of points in cluster 8 = 240901

Number of points in cluster 9 = 516591

Number of points in cluster 10 = 119297

Number of points in cluster 11 = 3843

Number of points in cluster 12 = 4825

Number of points in cluster 13 = 44369

Number of points in cluster 14 = 2777

K = 16

Loss in iteration 0: 393.8462187950793

Loss in iteration 1: 92.50817647684521

Loss in iteration 2: 43.62577227123545

Loss in iteration 3: 22.668375474946334

Loss in iteration 4: 21.56647220243458

Loss in iteration 5: 19.56901377722336
Loss in iteration 6: 18.793321065176727
Loss in iteration 7: 18.328696037505196
Loss in iteration 8: 18.178197180901705
Loss in iteration 9: 18.112593038240167
Loss in iteration 10: 18.06177007055808
Loss in iteration 11: 18.005796073579067
Loss in iteration 12: 17.968259413173975
Loss in iteration 13: 17.946171856855248
Loss in iteration 14: 17.918715112844474
Loss in iteration 15: 17.848758347405294
Loss in iteration 16: 17.740583196910364
Loss in iteration 17: 17.674019540006046
Loss in iteration 18: 17.654409649532646
Loss in iteration 19: 17.634773839613555
Loss in iteration 20: 17.53515711244873
Loss in iteration 21: 16.900468317365966
Loss in iteration 22: 15.978295570526813
Loss in iteration 23: 15.610029587131637
Loss in iteration 24: 15.439584250495614
Loss in iteration 25: 15.25475152091792
Loss in iteration 26: 14.97156903658366
Loss in iteration 27: 14.758077157591883
Loss in iteration 28: 14.65142483588222
Loss in iteration 29: 14.593878228634225

Loss in iteration 30: 14.557741743310567

Loss in iteration 31: 14.53292954146596

Loss in iteration 32: 14.514683171434614

Loss in iteration 33: 14.500204627175172

Loss in iteration 34: 14.488485623666069

Loss in iteration 35: 14.478632930513347

Loss in iteration 36: 14.47103751654677

Loss in iteration 37: 14.46373777914085

Loss in iteration 38: 14.453060341260866

Loss in iteration 39: 14.432075052428123

Loss in iteration 40: 14.354127498665358

Loss in iteration 41: 14.305935232765338

Loss in iteration 42: 14.301371739873758

Loss in iteration 43: 14.299551613775563

Loss in iteration 44: 14.298681358694584

Loss in iteration 45: 14.298337212911218

Loss in iteration 46: 14.298234329665416

Loss in iteration 47: 14.298193732936163

Loss in iteration 48: 14.298178705460794

Loss in iteration 49: 14.298168691221129

Coordinates of centroids are:

5.211295699547958 0.23406583980526213 234.7315393531933
22.211498782890814 37.75982380897183 0.7998145357598239
17.412657934392026

2.875490446878235 0.1688636981373403 239.33255416100425
12.054184986809439 37.59533136141978 0.4703813254456791
0.43240866576065234

5.925571572074326 0.175922651933702 235.51228026117545 25.217780010045175
2.6449020592667 69.54093420391763 11.908839779005525

3.9170198237885567 0.1732137521547574 237.62090308370188
16.48853667879708 37.10108216816702 0.5063685117793526 17.744349741428845

2.058255141579727 0.24056810730253364 239.02994336810735
9.792846497764556 17.41520119225037 0.6083457526080477 0.4944858420268256

3.21081143310837 0.20528245335450507 238.5714757840416 13.71996824136563
0.3305875347360063 22.163457721317982 17.684001587931718

2.440158464770025 0.15729905132776822 237.0098143925121
10.305280924439286 0.19359156829858043 0.4790027565991714
18.18812598875138

0.6871168189465519 0.1267721377083169 238.86459207758645
2.9886226652189087 0.05454777795203327 0.4429342301682727
0.3984526112185687

1.5177963042315956 0.12002389040805528 241.00329423017592
6.280099131055692 0.10099528641542274 0.38604125159585984
17.747065605852445

2.65747967804828 0.1884367344898262 238.7660445933107 11.347687846822936
0.2289156626506024 30.387791831225318 0.35619657051442283

6.4201580381471395 0.3060136239782018 234.6264850136239 27.46539509536788
71.54632152588556 1.6403269754768393 13.880108991825614

5.920230871767515 0.2401039722740605 235.03807251399581
25.297680618501847 36.0079978672354 33.01892828579046 12.016795521194348

4.016430481283433 0.23771824866310193 235.733330548129 17.076871657753944
37.88836898395722 0.9667446524064172 0.3292112299465241

4.192776351390261 0.18763652063784497 237.1888135398075
17.719428933279538 0.3917448621265327 36.09602210580853 17.55442979678775

3.188982635342192 0.25242900919305367 238.12889002383383
14.121586653047366 17.43224378617637 0.6283622744296902
17.984167517875385

0.4017560418144555 0.10489241456616247 243.45803153829814
1.7429117946493498 0.022391992924649575 0.3495523915301474
0.4225400816544802

Number of points in cluster 0 = 8627

Number of points in cluster 1 = 12509

Number of points in cluster 2 = 3982

Number of points in cluster 3 = 20884

Number of points in cluster 4 = 3355

Number of points in cluster 5 = 10076

Number of points in cluster 6 = 189001

Number of points in cluster 7 = 516483

Number of points in cluster 8 = 452734

Number of points in cluster 9 = 20003

Number of points in cluster 10 = 734

Number of points in cluster 11 = 3751

Number of points in cluster 12 = 5984

Number of points in cluster 13 = 17371

Number of points in cluster 14 = 5874

Number of points in cluster 15 = 777912

K = 17

Loss in iteration 0: 388.9165747062692

Loss in iteration 1: 64.27726673978661

Loss in iteration 2: 21.983251467013808

Loss in iteration 3: 20.683047558711063

Loss in iteration 4: 19.76243395928326

Loss in iteration 5: 18.66080407979825

Loss in iteration 6: 18.1615771905472
Loss in iteration 7: 18.063303058302505
Loss in iteration 8: 18.027525236665547
Loss in iteration 9: 17.99936627548106
Loss in iteration 10: 17.957009696687503
Loss in iteration 11: 17.92152449302062
Loss in iteration 12: 17.906554665509812
Loss in iteration 13: 17.887277583041456
Loss in iteration 14: 17.825694591591787
Loss in iteration 15: 17.69284523644844
Loss in iteration 16: 17.449959607032064
Loss in iteration 17: 16.603936610881718
Loss in iteration 18: 15.829081002445546
Loss in iteration 19: 15.530279753746903
Loss in iteration 20: 15.368972042108359
Loss in iteration 21: 15.153503326718369
Loss in iteration 22: 14.861482583830242
Loss in iteration 23: 14.658503301355335
Loss in iteration 24: 14.512687117361484
Loss in iteration 25: 14.325907447361624
Loss in iteration 26: 14.27238106179724
Loss in iteration 27: 14.249826647951505
Loss in iteration 28: 14.235518658243217
Loss in iteration 29: 14.22624950965134
Loss in iteration 30: 14.220289819592624

Loss in iteration 31: 14.216451551183107

Loss in iteration 32: 14.214056069357829

Loss in iteration 33: 14.212565804596682

Loss in iteration 34: 14.211636030879237

Loss in iteration 35: 14.21101567347641

Loss in iteration 36: 14.21063884494484

Loss in iteration 37: 14.210409885210797

Coordinates of centroids are:

5.223746547128692 0.23342888296583397 234.6335437363701
22.264453598255265 37.86382360067846 0.7904046522897988
17.392173491640417

2.8751399711399563 0.16878884078883993 239.34499198332537
12.051883918550523 37.60405643738977 0.4708994708994709
0.4320185986852654

5.925571572074326 0.175922651933702 235.51228026117545 25.217780010045175
2.6449020592667 69.54093420391763 11.908839779005525

3.938846337817649 0.1707849526656681 237.64881763826693
16.552326856003866 37.531589436970606 0.5001494768310912
17.746437468858993

2.058157499248567 0.24073459573189082 239.0313976555456 9.794229035166845
17.49263600841599 0.6101593026750827 0.4737000300571085

3.211195593926758 0.20536965366676524 238.56887367272037
13.721821970824658 0.33412722040289766 22.163838443981344
17.683437531011215

2.9059459331278243 0.2498064975100779 238.64672041735872
12.928954232866989 13.192553948304482 0.5283376808157458
18.057623903248754

0.6925052989271696 0.1269700216367212 238.82961443735076 3.01153931719391
0.0552395689982734 0.4443597876097832 0.396814146747701

2.438072493924422 0.15697132963768679 237.0081358705104 10.29516654224286
0.1762366906512911 0.4791577319969715 18.18721773062037

2.6581601040676315 0.18842597688497492 238.76750637914608
11.350567869114881 0.22904888177315255 30.39990994146195
0.35633161555010756

6.4201580381471395 0.3060136239782018 234.6264850136239 27.46539509536788
71.54632152588556 1.6403269754768393 13.880108991825614

5.921167778074139 0.24001387036543104 235.0363216857824 25.30141371032287
36.01333688983729 33.02667377967458 12.015737530008002

4.010686502659586 0.2373979388297875 235.7264145611708 17.052925531914827
37.87234042553192 0.9629321808510638 0.3291223404255319

4.192776351390261 0.18763652063784497 237.1888135398075
17.719428933279538 0.3917448621265327 36.09602210580853 17.55442979678775

3.675311456196895 0.25081394667448004 237.1836536771159 16.10125988866099
25.242894813946673 0.7658951069440375 17.802519777322004

1.5176109048862096 0.12000870197718068 241.00559610534447
6.27907568022748 0.09860914282429567 0.3859954765636918
17.747005931759343

0.40144015338956074 0.10500571650895608 243.4304549558194
1.7419387814771778 0.02249603938491584 0.3499467255948551
0.42329121391898733

Number of points in cluster 0 = 8254

Number of points in cluster 1 = 12474

Number of points in cluster 2 = 3982

Number of points in cluster 3 = 20070

Number of points in cluster 4 = 3327

Number of points in cluster 5 = 10077

Number of points in cluster 6 = 4217

Number of points in cluster 7 = 507933

Number of points in cluster 8 = 188871

Number of points in cluster 9 = 19987

Number of points in cluster 10 = 734

Number of points in cluster 11 = 3749

Number of points in cluster 12 = 6016

Number of points in cluster 13 = 17371

Number of points in cluster 14 = 3413

Number of points in cluster 15 = 452311

Number of points in cluster 16 = 786494

K = 18

Loss in iteration 0: 388.913916128757

Loss in iteration 1: 60.18663841559449

Loss in iteration 2: 21.92047708890365

Loss in iteration 3: 20.704172727057284

Loss in iteration 4: 19.77888952478673

Loss in iteration 5: 18.388707200031238

Loss in iteration 6: 17.078005170834498

Loss in iteration 7: 16.142214552446276

Loss in iteration 8: 15.722914188717695

Loss in iteration 9: 15.49053347258261

Loss in iteration 10: 15.255155449222082

Loss in iteration 11: 14.941732157661802

Loss in iteration 12: 14.701141544941736

Loss in iteration 13: 14.523921820014266

Loss in iteration 14: 14.359700025389706

Loss in iteration 15: 14.264047419732716

Loss in iteration 16: 14.227743005166449

Loss in iteration 17: 14.209630236344914

Loss in iteration 18: 14.198422291320469

Loss in iteration 19: 14.19144575450088

Loss in iteration 20: 14.187037373669392

Loss in iteration 21: 14.184209421449179

Loss in iteration 22: 14.182391892238158

Loss in iteration 23: 14.181184523072497

Loss in iteration 24: 14.180391807125117

Loss in iteration 25: 14.17984754053263

Loss in iteration 26: 14.179459960570075

Loss in iteration 27: 14.179209291056583

Loss in iteration 28: 14.179068052508402

Loss in iteration 29: 14.178982810445723

Loss in iteration 30: 14.178932297192532

Loss in iteration 31: 14.178905616908438

Loss in iteration 32: 14.17888869072373

Loss in iteration 33: 14.178877631987175

Loss in iteration 34: 14.178868635087442

Loss in iteration 35: 14.178863600419804

Loss in iteration 36: 14.178860625063944

Loss in iteration 37: 14.178858220124322

Coordinates of centroids are:

5.237156203288511 0.2332057797708015 234.60142625809644

22.320154459392008 37.91990533134031 0.7944693572496263

17.383408071748878

2.8747232401157037 0.16863693346190844 239.35440372870463
12.04951783992279 37.6093699774992 0.4690613950498232 0.43129218900675026
5.925571572074326 0.175922651933702 235.51228026117545 25.217780010045175
2.6449020592667 69.54093420391763 11.908839779005525
3.9502612977686624 0.16901954347268336 237.63100692485347
16.58526801744026 37.72885355219287 0.5006411900487304 17.732341626057963
3.3809257898603993 0.25718074944893454 237.611208670096
14.958780308596625 19.31778104335048 0.7027920646583394 17.88574577516532
3.21081143310837 0.20528245335450507 238.5714757840416 13.71996824136563
0.3305875347360063 22.163457721317982 17.684001587931718
2.734559923298185 0.24997379354426313 238.96034515819744
12.165484180249285 11.037392138063279 0.4966442953020134
18.090444231383827
0.6867335861197628 0.12674784451505194 238.86730517492018
2.9870096622192404 0.05476546351386104 0.44288810814259943
0.39853316807465256
2.4378163197185523 0.1568654823276317 237.0071169486183 10.2936924144725
0.17116577744104355 0.4791115867776477 18.18672678432349
2.65747967804828 0.1884367344898262 238.7660445933107 11.347687846822936
0.2289156626506024 30.387791831225318 0.35619657051442283
6.4201580381471395 0.3060136239782018 234.6264850136239 27.46539509536788
71.54632152588556 1.6403269754768393 13.880108991825614
5.920695118698307 0.2401552413977063 235.0371459055744 25.2992798079489
36.01013603627634 33.027207255268074 12.014403841024274
4.006128370554189 0.23735616211745258 235.72438709677465
17.033846153846085 37.86120760959471 0.9644334160463193
0.3296939619520265
4.192776351390261 0.18763652063784497 237.1888135398075
17.719428933279538 0.3917448621265327 36.09602210580853 17.55442979678775
3.8021495923431456 0.23894080113434912 237.26171924849294
16.54689826302725 29.103509393831974 0.6898263027295285 17.88089330024814

1.517553319563525 0.11999555946731416 241.00576632361162
6.2787186144108835 0.09744404000017691 0.3859636707813834
17.74725230982888

0.4017904313188217 0.10489117445743215 243.46019663068577
1.7430400234665981 0.022402231474286067 0.3495041454163686
0.4225121068802075

2.058043256233098 0.24071973565635346 239.02940823069994
9.793391408831509 17.48843496545509 0.6097927305497146 0.4728146590567738

Number of points in cluster 0 = 8028

Number of points in cluster 1 = 12444

Number of points in cluster 2 = 3982

Number of points in cluster 3 = 19495

Number of points in cluster 4 = 2722

Number of points in cluster 5 = 10076

Number of points in cluster 6 = 3129

Number of points in cluster 7 = 517169

Number of points in cluster 8 = 188741

Number of points in cluster 9 = 20003

Number of points in cluster 10 = 734

Number of points in cluster 11 = 3749

Number of points in cluster 12 = 6045

Number of points in cluster 13 = 17371

Number of points in cluster 14 = 2821

Number of points in cluster 15 = 452198

Number of points in cluster 16 = 777244

Number of points in cluster 17 = 3329

K = 19

Loss in iteration 0: 387.72775393370165
Loss in iteration 1: 29.393769877937626
Loss in iteration 2: 20.810780954477746
Loss in iteration 3: 18.81623741135853
Loss in iteration 4: 17.484116145815214
Loss in iteration 5: 16.13798342608509
Loss in iteration 6: 15.649749866162521
Loss in iteration 7: 15.253977790294265
Loss in iteration 8: 14.888311246379226
Loss in iteration 9: 14.706564294751228
Loss in iteration 10: 14.606461327619536
Loss in iteration 11: 14.532894386600724
Loss in iteration 12: 14.402691051159755
Loss in iteration 13: 13.855541215853632
Loss in iteration 14: 13.082232550704997
Loss in iteration 15: 12.74582556190865
Loss in iteration 16: 12.611646111725829
Loss in iteration 17: 12.560302174249324
Loss in iteration 18: 12.540897783878172
Loss in iteration 19: 12.532259378360877
Loss in iteration 20: 12.527891727342096
Loss in iteration 21: 12.525400012662713
Loss in iteration 22: 12.523963208778438
Loss in iteration 23: 12.5231670540392
Loss in iteration 24: 12.522692371749326

Loss in iteration 25: 12.522393766264189
Loss in iteration 26: 12.522202983417126
Loss in iteration 27: 12.52208708787658
Loss in iteration 28: 12.522016955730294
Loss in iteration 29: 12.521969172283681
Loss in iteration 30: 12.521938879736844
Loss in iteration 31: 12.521926481201376
Loss in iteration 32: 12.521918302806105
Loss in iteration 33: 12.521912555330596
Loss in iteration 34: 12.521908687813681
Loss in iteration 35: 12.52190283104979
Loss in iteration 36: 12.52189431392844
Loss in iteration 37: 12.521882579369935
Loss in iteration 38: 12.521857188031952
Loss in iteration 39: 12.521824112405422
Loss in iteration 40: 12.521789814247775
Loss in iteration 41: 12.521765291044362
Loss in iteration 42: 12.521737088264006
Loss in iteration 43: 12.52171276526444
Loss in iteration 44: 12.521689366532788
Loss in iteration 45: 12.52167340369667
Loss in iteration 46: 12.521664257829118
Loss in iteration 47: 12.5216602614946
Loss in iteration 48: 12.52165867862072
Loss in iteration 49: 12.521658106193666

Coordinates of centroids are:

5.237602189327053 0.23350391839780996 234.59393083716859
22.322975494464362 37.91503918397811 0.791640751337231 17.368329394203258

3.246252797031032 0.19054008623042046 238.16767614473622
13.679823173061225 37.75779075478906 0.6123451399879932
0.3921301096981935

5.925864355689517 0.17587691534790287 235.51179603114812
25.218889726199418 2.645566440592816 69.54559155990957 11.91183119819141

3.9506279475087176 0.16907268812794565 237.63094474062004
16.586856674184844 37.72898298134099 0.5007176542956736
17.729239286446585

3.7577866184448476 0.23810922242314606 237.374502712477 16.3549367088607
29.163110307414104 0.6839059674502712 17.90235081374322

3.209990270055594 0.20523054011119876 238.5743655679114 13.716064336775226
0.3232724384432089 22.16590548054011 17.683379666401905

2.699390925589842 0.2503774954627948 238.9021814882029 11.991288566243197
10.18983666061706 0.4827586206896552 18.091833030852996

1.7979496420677454 0.1562763830699679 239.39391053343266
7.619082571833958 0.15223666413749876 0.5441559726849866
0.3574786395275954

2.4353150403490536 0.15679482345963766 237.00791180394782
10.282701798233294 0.16898417808654395 0.4792324148010082
18.19926185584479

2.661516811579623 0.18841956073779942 238.76340955922927
11.364336332110328 0.22928079609991456 30.469417500125648
0.35638538473136655

6.4134634146341485 0.30597831978319806 234.62758807588068
27.436585365853688 71.46883468834689 1.6314363143631436
13.804878048780488

5.914698353690905 0.24027031332979315 235.0393441317043
25.273499734466395 36.01938396176315 32.96229421136484 11.963621879978758

2.074494081942332 0.239473748103187 239.04518664643393 9.8536570561457
18.327465857359634 0.6267071320182094 0.47678300455235206

4.192776351390261 0.18763652063784497 237.1888135398075
17.719428933279538 0.3917448621265327 36.09602210580853 17.55442979678775

4.318621212121211 0.28753030303030286 234.90473484848457
18.921590909090938 18.645833333333332 1.0378787878787878
17.62405303030303

0.36685441936658997 0.11399245358574621 239.47484927195487
1.6413880597003507 0.026605387695668 0.39896796505278487
0.42430833636694576

0.3991132193050548 0.10508983373141907 243.94899500346082
1.7291915973410925 0.02253973288734459 0.34816277948387697
0.41594858313669136

2.909743543271406 0.23958948799275054 239.09644313547764
12.977797915722691 18.689623923878568 0.5573176257362936
18.024014499320344

1.517133744455142 0.1199616886394034 241.0081467200369 6.276872847364137
0.09704009987338746 0.3858716343642368 17.74637870430217

Number of points in cluster 0 = 8039

Number of points in cluster 1 = 18323

Number of points in cluster 2 = 3981

Number of points in cluster 3 = 19508

Number of points in cluster 4 = 2765

Number of points in cluster 5 = 10072

Number of points in cluster 6 = 2755

Number of points in cluster 7 = 121252

Number of points in cluster 8 = 188852

Number of points in cluster 9 = 19897

Number of points in cluster 10 = 738

Number of points in cluster 11 = 3766

Number of points in cluster 12 = 3295

Number of points in cluster 13 = 17371

Number of points in cluster 14 = 1056

Number of points in cluster 15 = 549400

Number of points in cluster 16 = 624231

Number of points in cluster 17 = 2207

Number of points in cluster 18 = 451772

K = 20

Loss in iteration 0: 387.7230303619908

Loss in iteration 1: 29.38546019890945

Loss in iteration 2: 20.804523830832903

Loss in iteration 3: 18.809814696976684

Loss in iteration 4: 17.449014113904013

Loss in iteration 5: 15.945484506482128

Loss in iteration 6: 15.440231313362801

Loss in iteration 7: 15.090835072101319

Loss in iteration 8: 14.8289787227718

Loss in iteration 9: 14.663115390341243

Loss in iteration 10: 14.566712474518301

Loss in iteration 11: 14.502940896139213

Loss in iteration 12: 14.429020871440883

Loss in iteration 13: 14.227526437000076

Loss in iteration 14: 13.918371516963889

Loss in iteration 15: 13.727435285637213

Loss in iteration 16: 13.567211264849732
Loss in iteration 17: 13.418486200243521
Loss in iteration 18: 13.276000002745821
Loss in iteration 19: 13.160135406440029
Loss in iteration 20: 13.091725187533976
Loss in iteration 21: 13.051470823054204
Loss in iteration 22: 13.02341887246383
Loss in iteration 23: 12.997589053004619
Loss in iteration 24: 12.97235197954371
Loss in iteration 25: 12.958043086738728
Loss in iteration 26: 12.952762300092514
Loss in iteration 27: 12.950744877309265
Loss in iteration 28: 12.949828740436361
Loss in iteration 29: 12.949344587205616
Loss in iteration 30: 12.949051632533514
Loss in iteration 31: 12.948842930016195
Loss in iteration 32: 12.948692453734706
Loss in iteration 33: 12.948577578213483
Loss in iteration 34: 12.948488661203639
Loss in iteration 35: 12.948425439388778
Loss in iteration 36: 12.948377304413878
Loss in iteration 37: 12.948340208327178
Loss in iteration 38: 12.948310059599624
Loss in iteration 39: 12.948279094888322
Coordinates of centroids are:

5.240173139564043 0.23304961162615812 234.6036895514906
22.331621147581927 37.94713104485091 0.794287146078677 17.38524179403658

2.8750529364440744 0.16860466613032904 239.3626065969429
12.050506838294378 37.61238938053097 0.4723250201126307
0.43177795655671763

5.925571572074326 0.175922651933702 235.51228026117545 25.217780010045175
2.6449020592667 69.54093420391763 11.908839779005525

3.9519235695104347 0.16887368312331955 237.64915719892696
16.589506300351054 37.75537079115885 0.5006713488948564
17.735488535426565

3.630068698596997 0.2620145137880988 237.0731494920173 15.970875665215303
22.490082244799225 0.8006773101112724 17.810353168843736

3.2115833167825167 0.2052129096325714 238.55834061569055
13.724111221449858 0.33028798411122146 22.204071499503474
17.68311817279047

2.5862617000955073 0.24868767908309453 238.90902578796553
11.481852913085028 8.93170964660936 0.4885386819484241 17.947946513849093

2.056042565947237 0.2405497601918467 239.0315407673862 9.785311750599547
17.461330935251798 0.6106115107913669 0.4661270983213429

1.4783611333000604 0.12797441337992543 237.84710634048412
6.214210351140028 0.10466383757696789 0.42377267432185056
16.886233150274588

2.65747967804828 0.1884367344898262 238.7660445933107 11.347687846822936
0.2289156626506024 30.387791831225318 0.35619657051442283

6.4201580381471395 0.3060136239782018 234.6264850136239 27.46539509536788
71.54632152588556 1.6403269754768393 13.880108991825614

5.921225186766262 0.24007790821771635 235.03651013874023
25.301440768409933 36.01307363927428 33.03094983991462 12.014674493062968

4.002837762006945 0.23726357484733468 235.7159465258298
17.020300379600528 37.854431424327444 0.9565934972767783
0.3289321670242614

4.193493775933621 0.18762759336099613 237.18701590594725
17.72226832641764 0.3919432918395574 36.103331028123556 17.55411479944675

3.8335124210526264 0.23324463157894704 237.09789894736824
16.636378947368435 30.442947368421052 0.6846315789473684
17.81642105263158

0.6850848565632623 0.1265829730512991 238.87200933064253
2.9796202067038697 0.054532985608036315 0.44269100743745776
0.38701052834927074

0.40199410115395545 0.1048977249885221 243.46413904940755
1.7438833940646623 0.022412522355827462 0.3494479978971348
0.42327634637487693

3.019787660256413 0.24841586538461569 238.60146233974365
13.45320512820511 15.520833333333334 0.5268429487179487
18.134615384615383

1.5838254230394901 0.11486190787728602 242.27127072760914
6.514474051808315 0.09962691185571568 0.37574396605074706
18.341907877287596

2.904670898165136 0.1752178094811432 238.01053490985814
12.243933772259085 0.18677473609479459 0.4849686018306443
18.72398346842012

Number of points in cluster 0 = 7982

Number of points in cluster 1 = 12430

Number of points in cluster 2 = 3982

Number of points in cluster 3 = 19364

Number of points in cluster 4 = 2067

Number of points in cluster 5 = 10070

Number of points in cluster 6 = 2094

Number of points in cluster 7 = 3336

Number of points in cluster 8 = 240360

Number of points in cluster 9 = 20003

Number of points in cluster 10 = 734

Number of points in cluster 11 = 3748

Number of points in cluster 12 = 6059

Number of points in cluster 13 = 17352

Number of points in cluster 14 = 2375

Number of points in cluster 15 = 517650

Number of points in cluster 16 = 776084

Number of points in cluster 17 = 2496

Number of points in cluster 18 = 282775

Number of points in cluster 19 = 118319

Additional Requirements:

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

Stopping Criteria:

The stopping criteria used in the algorithm is convergence. If the centroids in the previous iteration are almost the same as the centroids in the current iteration, at that point the algorithm stops or converges for a given value of 'k' where 'k' is the number of clusters used in the algorithm. Because convergence criteria is quite strict for this algorithm, it took a very long time to run the algorithm for k= 2 to 20. However, the results should be quite accurate.

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

Centroid Initialization:

The algorithm initializes first 'k' data points as centroids for a given value of k. It then optimizes and updates the centroids by determining the mean values of the coordinates of the data points which belong to the same centroid. Because the algorithm used first k data points as centroids, it might be possible that these data points are quite closer to each other, hence it is taking longer time to execute.

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

The algorithm may require different amounts of time to run on the same input and parameters:

- If the centroids are initialized differently - i.e if they are initialized randomly, the algorithm may take less time depending on the initialized centroids.
- If the loss function is considered as the stopping criteria, the algorithm may stop if loss gets stable and hence takes less time. However, it is possible that algorithm didn't converge for given value of k i.e the centroids in the previous iteration are not the same as the centroids in the current iteration

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

K-means generally needs some initial cluster assignment or set of cluster centers to start with. The algorithm may produce different results on the same input and parameters due to initialization problem for k means, as when kmeans starts it picks up the random initial points to cluster the data. So, if centroids are initialized randomly, the algorithm may produce coordinates of centroids differently. The two differing results might hence likely be two local minima of the function (minimal distances to class means) that k-means optimizes. The algorithm selects k number of random points and calculates the distance of points in data to these locations and finds new centroids to further minimize the distance. So because of these random initial points we get different results for centroid locations, but the answer is very similar.