

Assignment #2

Image Segmentation

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Problem Statement:

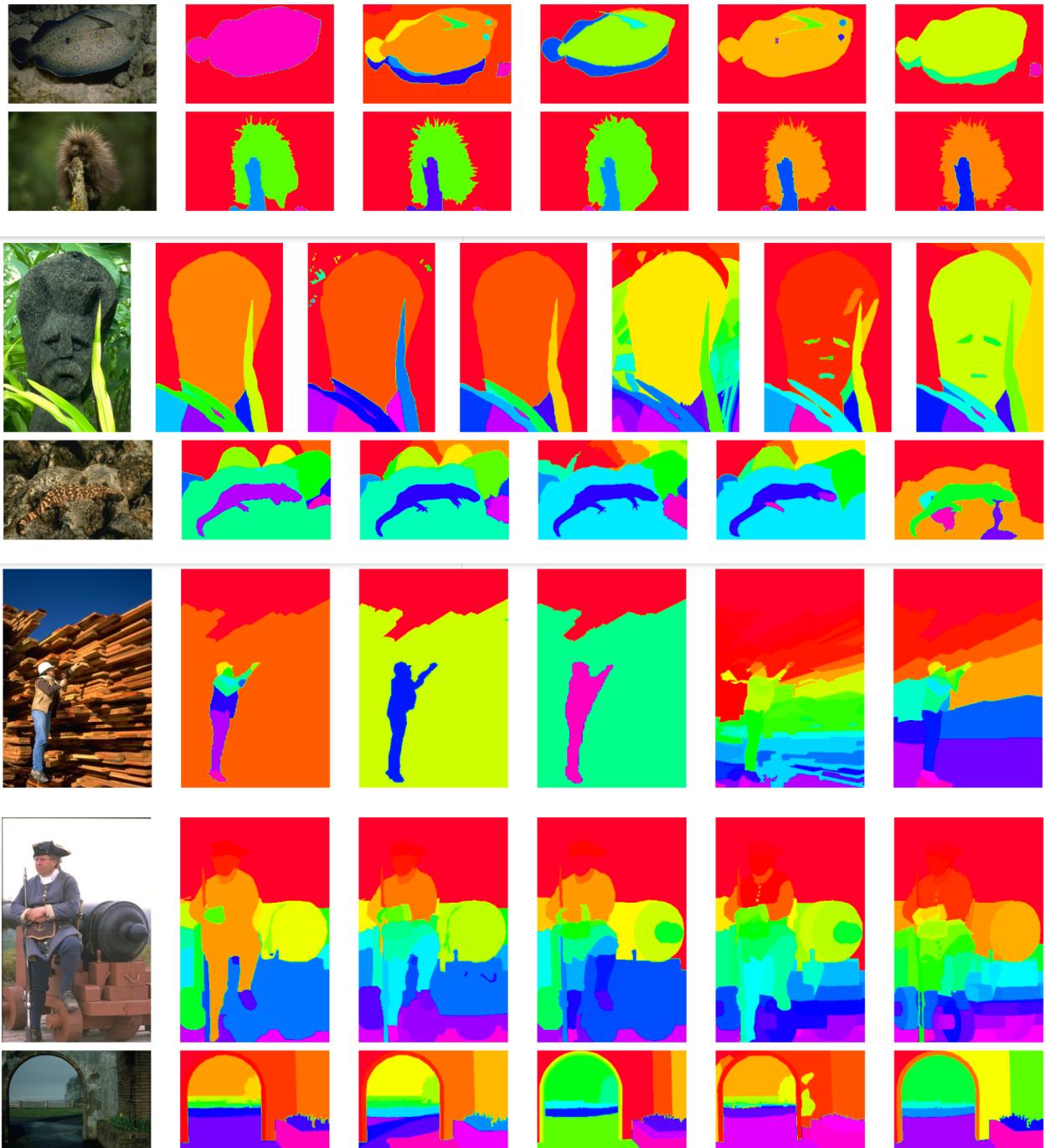
We performed image segmentation. Image segmentation means that we can group similar pixels together and give these grouped pixels the same label. The grouping problem is a clustering problem. We studied the use of K-means on the Berkeley Segmentation Benchmark. Below we will show the steps we did to achieve the goal of this assignment.

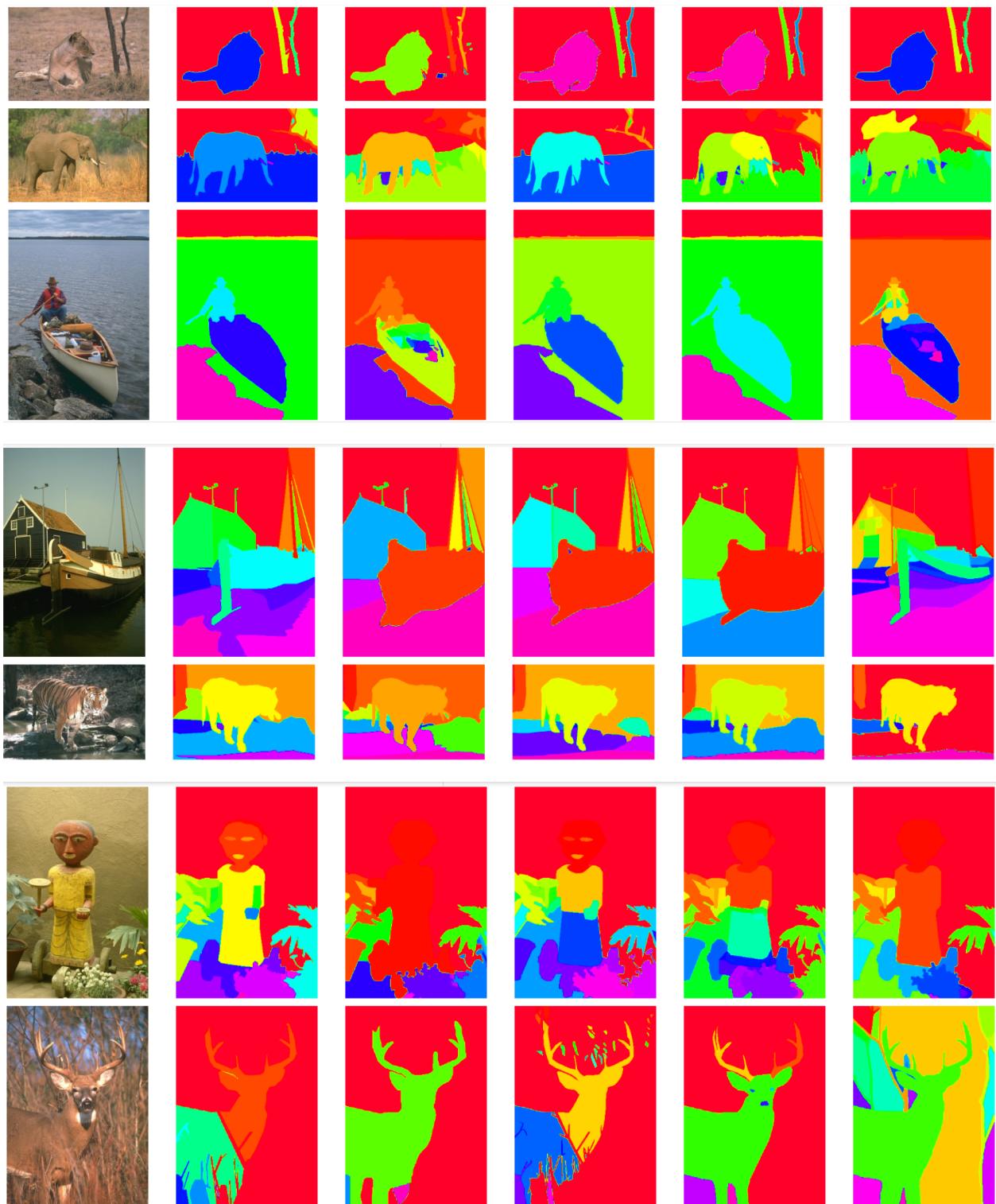
Step 1: Download the Dataset and Understand the Format

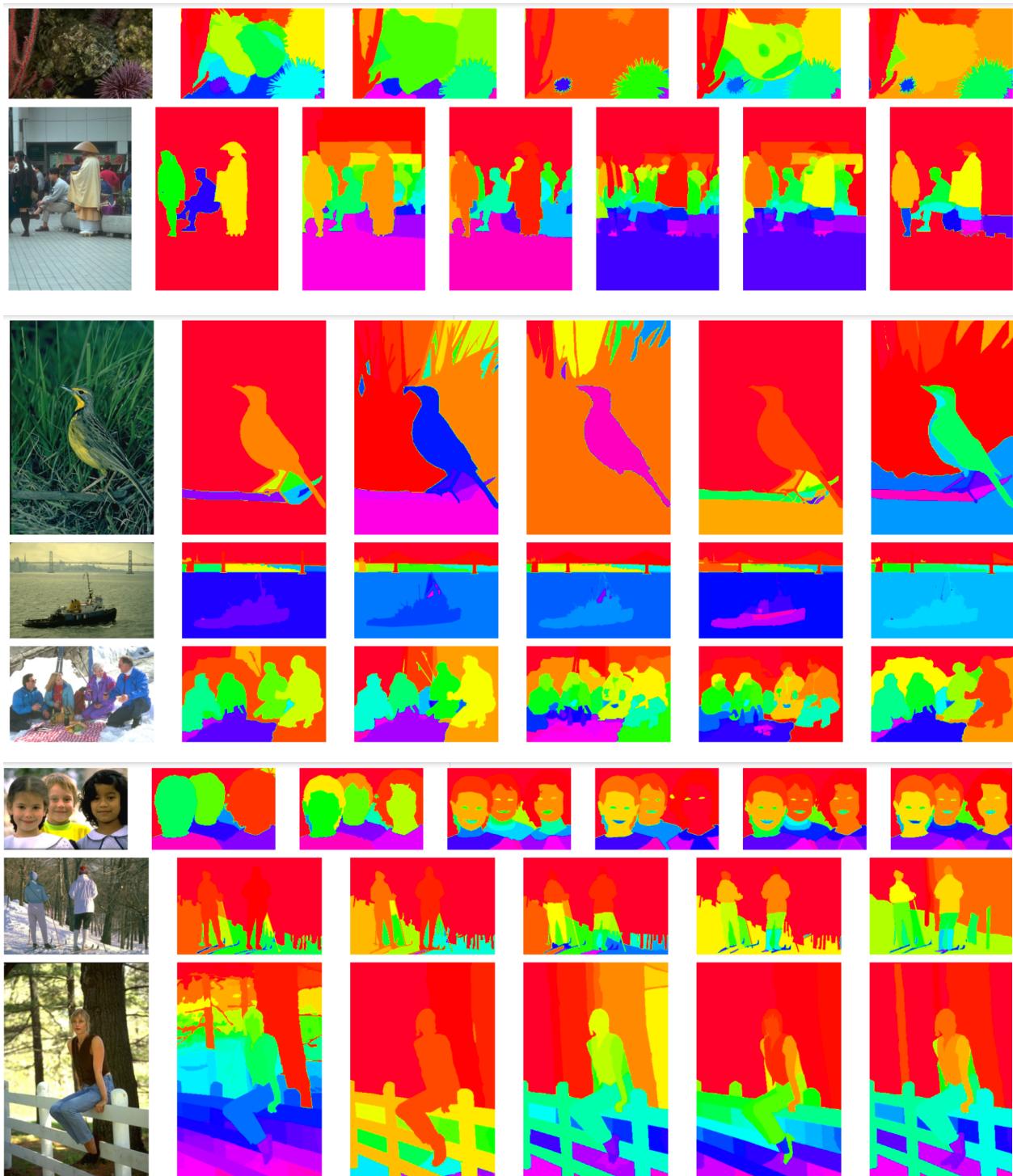
We uploaded the data set to google drive and mounted the drive to colab to read the data from it.

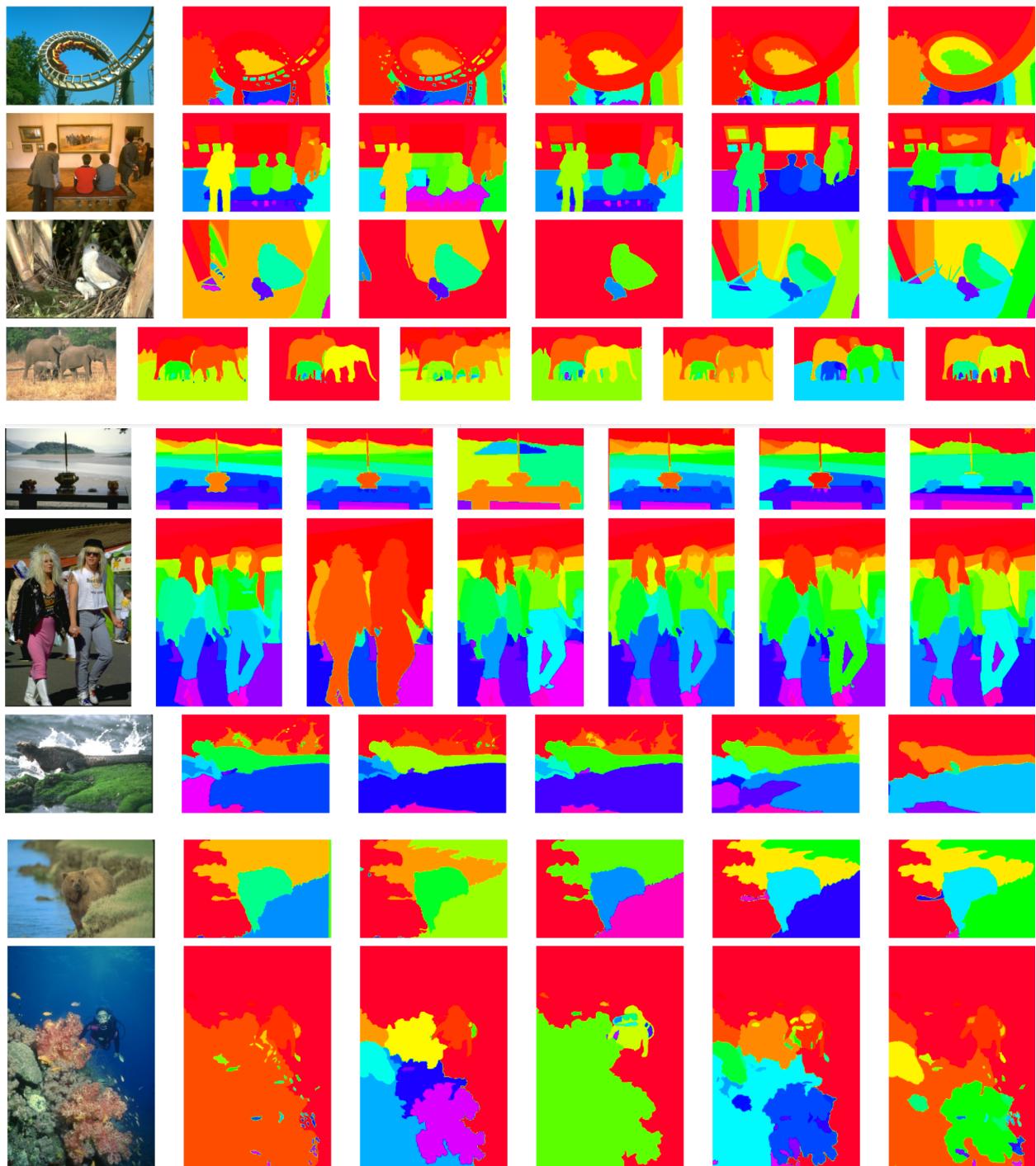
We understood the format especially that of the ground truth to be able to read and visualize them as shown in the next section.

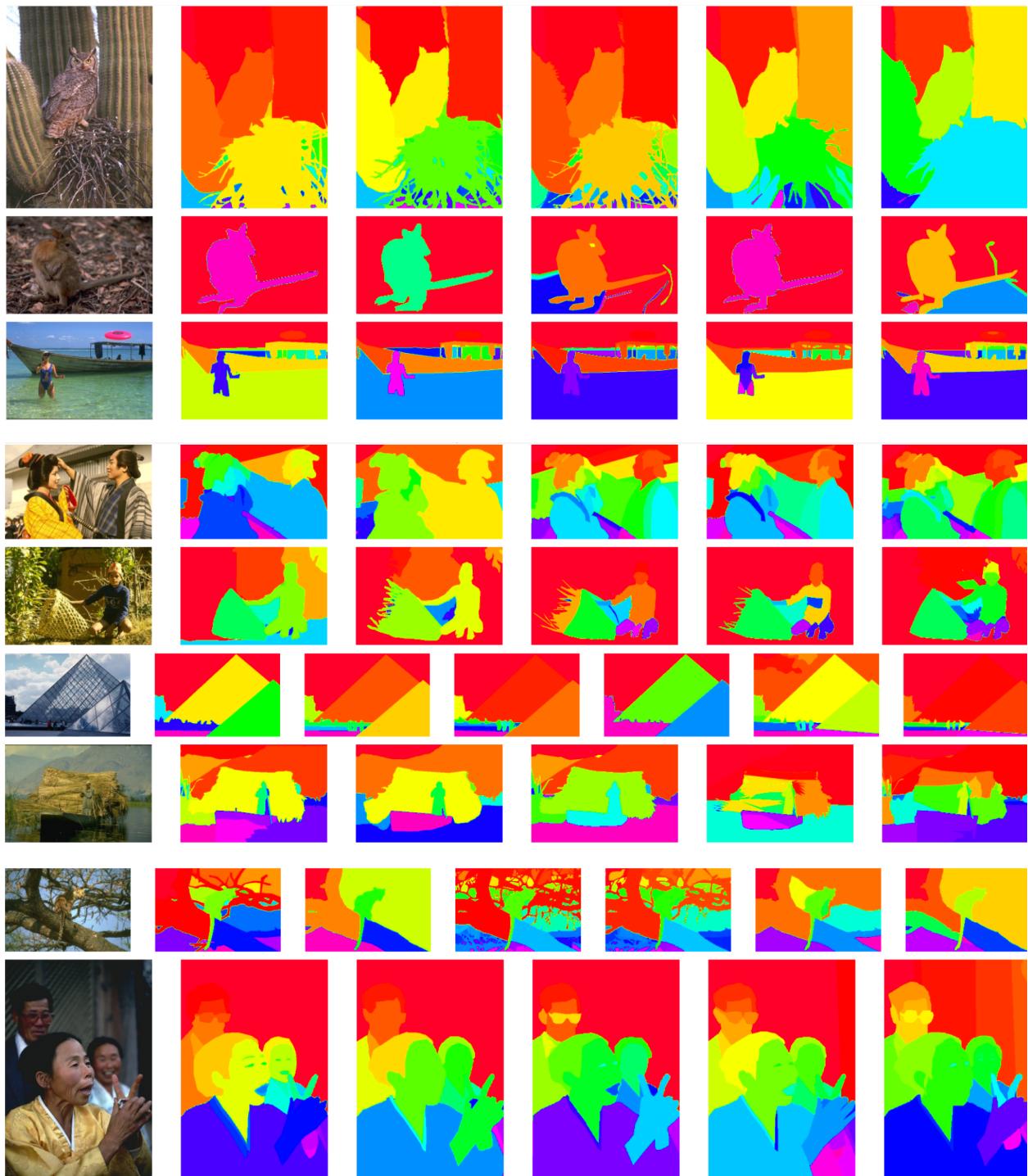
Step 2: Visualize the image and the ground truth segmentation

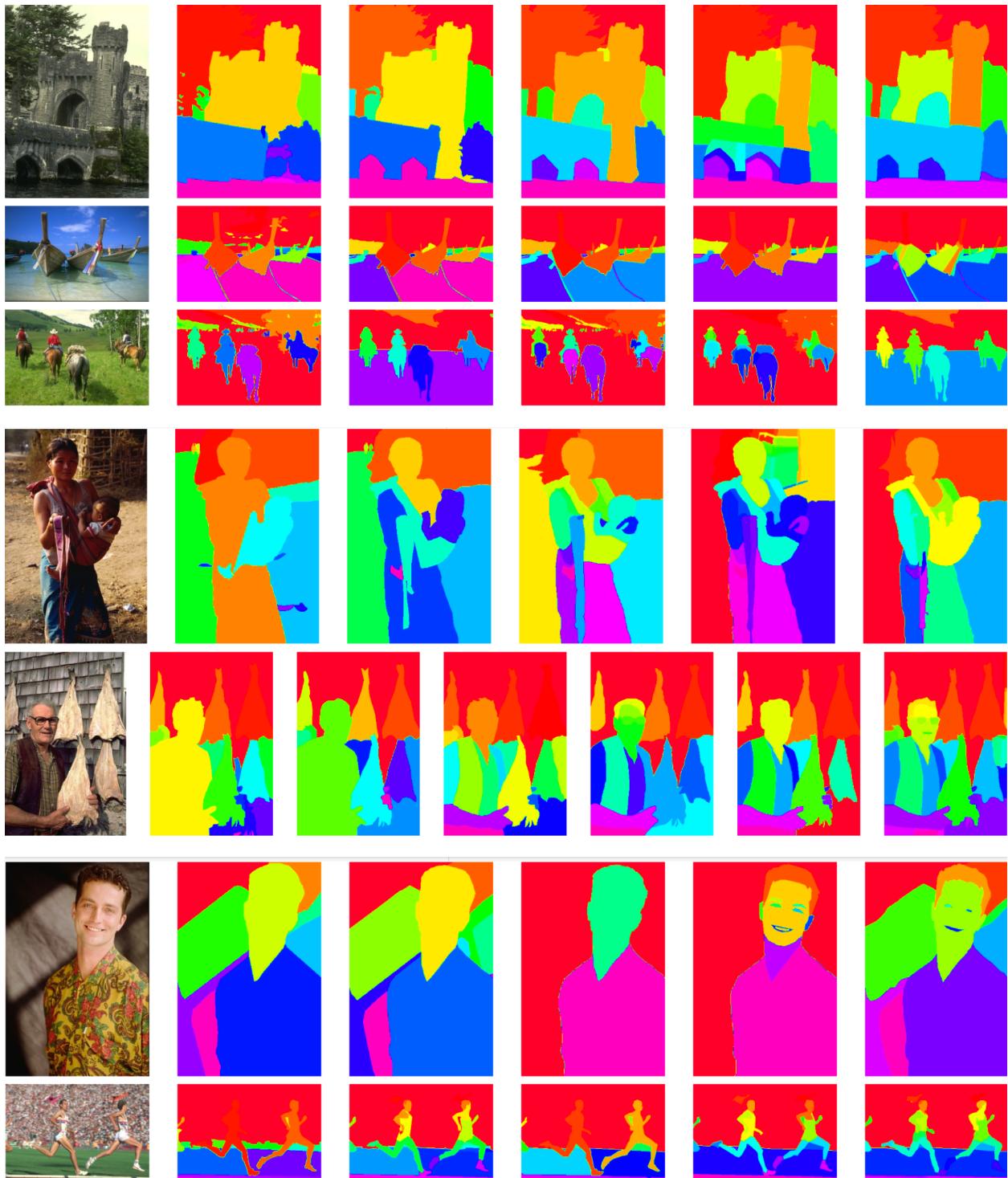


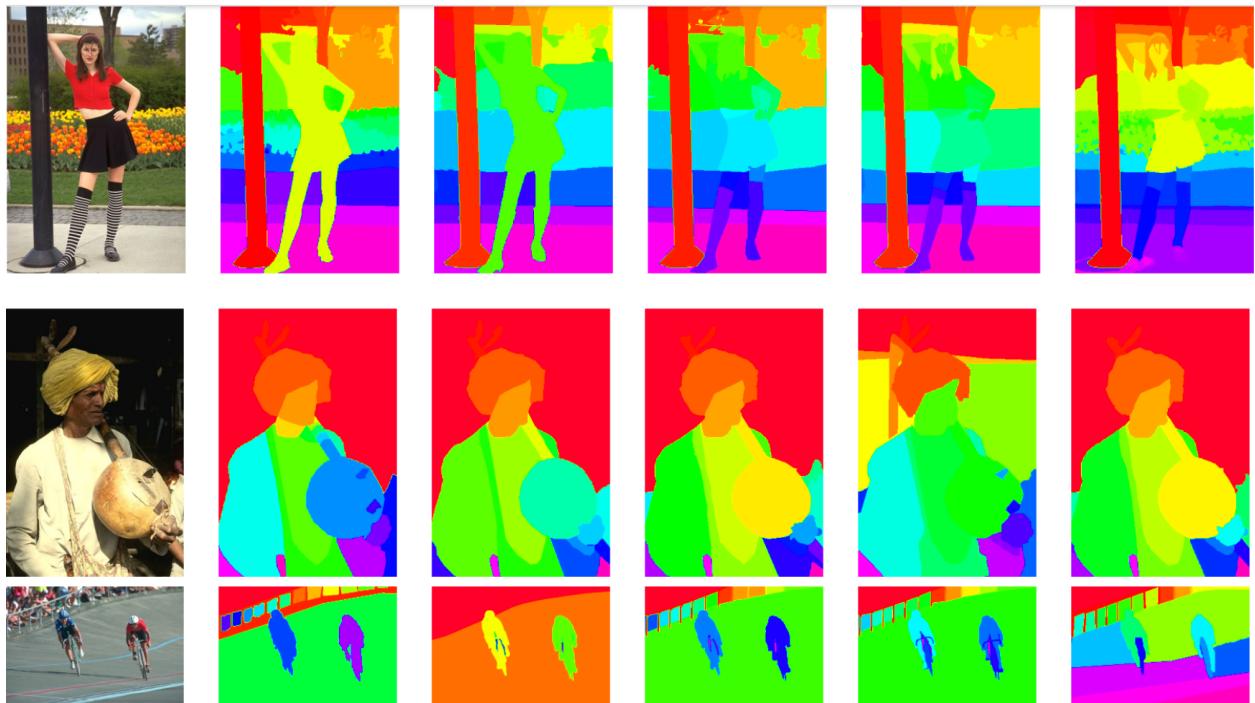












Step 3:Segmentation using K-means

We implemented the K-means algorithm using the pseudo code in the lecture.

We displayed the result segmentation of every image at $K=[3, 5, 7, 9, 11]$

We displayed the results where every row contains the segmentations at every K of an image.

We evaluated the result segmentation using

F-measure, Conditional Entropy for image I with M available ground-truth segmentations. For a clustering of K-clusters we reported the measures M times and the average of the M trials as well. We reported the average per dataset as well.

Observation:

We observed that as K increases the F-measure and the conditional entropy between the resulted segmentation and each ground truth decreases.

c) We saw that good images are the images with higher F-measure and lower entropy . while bad images are with lower F-measure and higher entropy .

For example at $K = 3$ The best images We got in this report are images '5' , '9'

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K = 3
F measure : 0.5501247131642256,0.5258535315800296,0.5684944000042026,0.5455833684334997,0.555675999458374
Average of F-measure : 0.5490887210253989
Conditional Entropy : 1.6263360219512393,2.182077741864286,1.405106211052742,2.08575283630408645,2.4071220611851416
Average of Conditional Entropy : 1.941278974471495
K = 5
F measure : 0.41389139446309653,0.41054516058727897,0.4196618588292319,0.4973734867494894,0.40880952047161473
Average of F-measure : 0.43005628422014236
Conditional Entropy : 1.5177828993830742,2.0641322452336173,1.312134782919591,1.919525434156304,2.258422756150569
Average of Conditional Entropy : 1.814396235686308
K = 7
F measure : 0.31547446038490795,0.327743229066633463,0.3198517914554277,0.42315251098660006,0.3510293453277783
Average of F-measure : 0.347450267442097
Conditional Entropy : 1.480013943623245,2.0196507166065985,1.2802723826948368,1.8837688758896423,2.205011181824129
Average of Conditional Entropy : 1.7737434302755862
K = 9
F measure : 0.25440369091393694,0.2624081664208258,0.24987988542144512,0.3411240725868476,0.27995142001474393
Average of F-measure : 0.2775534470715599
Conditional Entropy : 1.4706785316366724,2.0076492107705386,1.2757425577967862,1.8791962364644617,2.18865673567338
Average of Conditional Entropy : 1.7643846544683677
K = 11
F measure : 0.2126873759904937,0.22936417640882008,0.2059464041869442,0.297865156893861,0.2347680414542655
Average of F-measure : 0.2343262309868769
Conditional Entropy : 1.4685794417780609,2.005581563571241,1.273898546968553,1.8774938166295914,2.1865021550186887
Average of Conditional Entropy : 1.7624111047916273

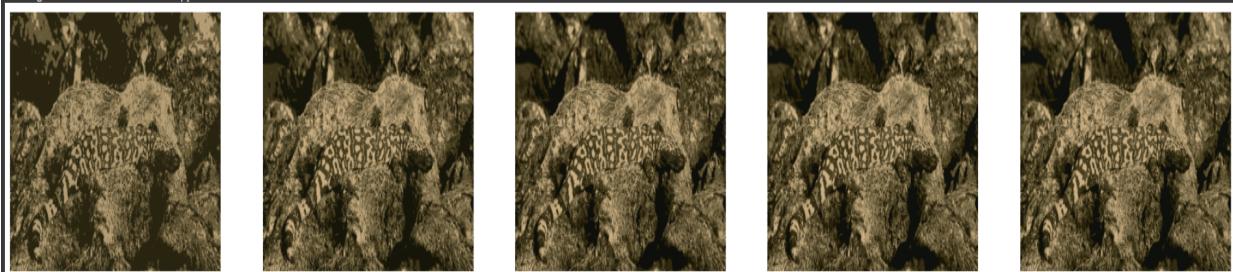
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K = 3
F measure : 0.397761659371239,0.391212560525299,0.3900169642488616,0.4018713440292366,0.45354565129357854
Average of F-measure : 0.40688157499908917
Conditional Entropy : 2.2404461066866386,2.5329942065801805,2.5036305964562775,2.2595166227506676,1.6910426961642941
Average of Conditional Entropy : 2.2455260457276114
K = 5
F measure : 0.2844863803665621,0.2812667866395663,0.28058518423449813,0.28678220211054084,0.33611617049255266
Average of F-measure : 0.293847344768744
Conditional Entropy : 2.2030848456869947,2.4713006237996646,2.447785481185976,2.2088739945058284,1.6509482583551935
Average of Conditional Entropy : 2.1963986407067315
K = 7
F measure : 0.21845678849124958,0.21678438557001461,0.2162784817079181,0.22014246273367707,0.26533141126245463
Average of F-measure : 0.2273987059538628
Conditional Entropy : 2.1815908481503445,2.4348179533263155,2.4232236330793104,2.181452616577535,1.6169983178988808
Average of Conditional Entropy : 2.167616673806463
K = 9
F measure : 0.1968593159524346,0.17306138982168495,0.17265270406930358,0.17542141150608961,0.21527097629494532
Average of F-measure : 0.1866531595288916
Conditional Entropy : 2.1678945763460553,2.4185785426217137,2.407566278113031,2.1674627478806507,1.6012991587179257
Average of Conditional Entropy : 2.152558660735875
K = 11
F measure : 0.16344649314400708,0.14357917897699574,0.1432463456242526,0.14541121771074653,0.1796992676896202
Average of F-measure : 0.1558765006291243
Conditional Entropy : 2.1635388192457787,2.412830271657623,2.4021238506974907,2.16193642961665,1.5965488574836746
Average of Conditional Entropy : 2.147395645740244

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K = 3
F measure : 0.45338919855147974, 0.47748255374173554, 0.4472952991840132, 0.5922397583236368, 0.5137833587918614
Average of F-measure : 0.4968380337185453
Conditional Entropy : 3.067666708010333, 2.124706621025267, 3.3026529525344515, 2.0765228280765946, 2.78762140978425
Average of Conditional Entropy : 2.6718341038861793
K = 5
F measure : 0.4740082570552252, 0.46701230442829916, 0.47618706070859806, 0.52781307188118, 0.46855263989550916
Average of F-measure : 0.4821466662128865
Conditional Entropy : 2.79912627638985, 1.925768272065804, 2.9761479929863373, 1.911243944261257, 2.5668209711901677
Average of Conditional Entropy : 2.43582149062851
K = 7
F measure : 0.42348804350488957, 0.3796500453746347, 0.43104144239154446, 0.3949071732815867, 0.4003860751932003
Average of F-measure : 0.4058930342579724
Conditional Entropy : 2.6992492388545726, 1.8673704415027315, 2.843234554991339, 1.8345467849261006, 2.4881690567376693
Average of Conditional Entropy : 2.346514015402488
K = 9
F measure : 0.38070782404321163, 0.3362151886586815, 0.38825311606797697, 0.37746342488661777, 0.3562737004756424
Average of F-measure : 0.367782650826426
Conditional Entropy : 2.6182421317852236, 1.8847020761547932, 2.7697211584307615, 1.7468546280286703, 2.4054890602641894
Average of Conditional Entropy : 2.2690018109327275
K = 11
F measure : 0.33874539080850163, 0.29072792075214976, 0.33450384194389906, 0.33099027836620576, 0.3145594506772233
Average of F-measure : 0.3259053749099599
Conditional Entropy : 2.5840963032552065, 1.7845364482994992, 2.7310076574448168, 1.7164361864599054, 2.3760346398015035
Average of Conditional Entropy : 2.238422247052186

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K = 3
F measure : 0.4312589408645456, 0.46630778686722146, 0.4455975998011458, 0.4296311270935089, 0.47883301095495584, 0.3888898140955335, 0.4686604913677445
Average of F-measure : 0.44416598859409656
Conditional Entropy : 2.5056496290016344, 2.3592437472265457, 2.485903870213935, 2.980461542349933, 1.9210414671690579, 3.70935979394436, 3.0145587772799
Average of conditional Entropy : 2.710888918255061
K = 5
F measure : 0.37613664041947614, 0.4124926586971001, 0.39156841701166095, 0.3636051477339232, 0.4060625278863058, 0.3339982198383914, 0.3936502976809921
Average of F-measure : 0.3823727873447567
Conditional Entropy : 2.441122019876958, 2.304320746986221, 2.422924704578693, 2.9149390907097374, 1.8775081984886555, 3.6194007923940297, 2.9464178597395
Average of Conditional Entropy : 2.6466615968361387
K = 7
F measure : 0.33263892285546, 0.36151040438080956, 0.3458296328721889, 0.3285390874893671, 0.3537907301618885, 0.30861403934777953, 0.3499450963329535
Average of F-measure : 0.3401239876343496
Conditional Entropy : 2.367739063801893, 2.227584795607837, 2.344066466818306, 2.8387463942641165, 1.8052776847538239, 3.526941517441129, 2.8648576113985436
Average of Conditional Entropy : 2.5667447905839498
K = 9
F measure : 0.2641679677254953, 0.28596079453239226, 0.274343449630691, 0.2604954862953762, 0.27842592587866055, 0.24505793895849737, 0.27672416097225866
Average of F-measure : 0.2693108177289719
Conditional Entropy : 2.366972648541617, 2.229240128235385, 2.345237687787237, 2.832204587630752, 1.8087797052122032, 3.528106255869579, 2.865227456923525
Average of Conditional Entropy : 2.567966251281303
K = 11
F measure : 0.22867608708115794, 0.25742562785364453, 0.2380093473744619, 0.2381206089369159, 0.23986536981718097, 0.22988853949409718, 0.25120284465527626
Average of F-measure : 0.24045549360181925
Conditional Entropy : 2.306379443949787, 2.1730469019870866, 2.280184657958041, 2.766244290383187, 1.763381621151022, 3.4557893814981653, 2.795851255610067
Average of Conditional Entropy : 2.5058396503511418

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K = 3
F measure : 0.7351087766519057,0.6203895446205042,0.7312682161068812,0.6019740334229735,0.5629682340601811
Average of F-measure : 0.6503417609724892
Conditional Entropy : 1.4142346184230532,2.4883949268130614,2.0010901169506328,1.9971608018423765,2.8204126647140964
Average of Conditional Entropy : 2.144258625748644
K = 5
F measure : 0.5549552229597156,0.4867179148323075,0.5506358960983876,0.46582123639563633,0.440888268032247
Average of F-measure : 0.49980370767385435
Conditional Entropy : 1.0146705955715822,2.064326623378432,1.597759233542865,1.58697476574802,2.3891801143889366
Average of Conditional Entropy : 1.7305822664866515
K = 7
F measure : 0.4697624870420506,0.41227057317976135,0.44234600429409204,0.4188052657482971,0.37364329662139056
Average of F-measure : 0.4233655253771132
Conditional Entropy : 1.023002696587973,0.0633597243495307,1.5965561705153475,1.5957027523660994,2.380982452382161
Average of Conditional Entropy : 1.7319207592543873
K = 9
F measure : 0.4084174765467064,0.3668204933458776,0.39268270689473767,0.36877672067732675,0.32464377363490454
Average of F-measure : 0.37226823421991057
Conditional Entropy : 1.8122299020579897,2.0372105917006786,1.5668015704163036,1.5767175999391168,2.344414725853086
Average of Conditional Entropy : 1.707474877993435
K = 11
F measure : 0.3586217036544487,0.3193731476533654,0.34171381119239846,0.3042460903354893,0.28905858099400333
Average of F-measure : 0.32260266676594107
Conditional Entropy : 0.996065873957975,2.0125089842301302,1.5414080023230299,1.5580901582567377,2.310514235790526
Average of Conditional Entropy : 1.6837174509116803

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K = 3
F measure : 0.5330958262019513,0.5260085761104153,0.5315153972625534,0.4550553700151931,0.23143698952061542
Average of F-measure : 0.4554224318221456
Conditional Entropy : 1.97270507183225,2.4370174950585577,2.128130382162117,2.6097110713612737,4.33458966695224
Average of Conditional Entropy : 2.694830734599099
K = 5
F measure : 0.48283110857905,0.45277964754977795,0.4664542867157963,0.42043348540029035,0.2474644174443666
Average of F-measure : 0.4136889923936414
Conditional Entropy : 1.8850831963164625,2.3344108208469394,2.03212672191529,2.5232416781467872,4.189013648044589
Average of Conditional Entropy : 2.592775213053998
K = 7
F measure : 0.3958563358270286,0.38982258278924753,0.3877522406811618,0.36102987813981685,0.24214380594527898
Average of F-measure : 0.35532096867650675
Conditional Entropy : 1.8467028200943152,2.292121814837609,1.99347757346366,2.4829154554751933,4.13969225564637
Average of Conditional Entropy : 2.559883214663624
K = 9
F measure : 0.3824579771529979,0.3701623149173858,0.37799621472420764,0.35868823903724234,0.2765741984324046
Average of F-measure : 0.3531757888528476
Conditional Entropy : 1.7368241231221742,2.177343089382512,1.8821209841009772,2.3616829794428478,3.9590955232334197
Average of Conditional Entropy : 2.423413339856386
K = 11
F measure : 0.3133347005570845,0.31158630344135774,0.3179547485335635,0.3030426050627418,0.2321629681436027
Average of F-measure : 0.29561626514767003
Conditional Entropy : 1.7624395115884852,2.1952212791313093,1.908626928954324,2.3784523902010655,3.97466828260631
Average of Conditional Entropy : 2.44444138762163

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K = 3
F measure : 0.38238853240132475, 0.5800772635164946, 0.5736598936941744, 0.5639816545507458, 0.5655010089126119
Average of F-measure : 0.5331216706156703
Conditional Entropy : 1.17220986286895818, 1.6915649039379532, 1.6818126637665202, 1.7716280991022986, 1.9584444473898115
Average of Conditional Entropy : 1.655131995411833
K = 5
F measure : 0.42076452985176216, 0.5832301169592394, 0.5806229758642667, 0.56900833738547, 0.5135529127968489
Average of F-measure : 0.5334357745715175
Conditional Entropy : 0.9867676429489493, 1.421447896775828, 1.4064096441230118, 1.583139169479584, 1.6622700264775877
Average of Conditional Entropy : 1.396006876635002
K = 9
F measure : 0.492387269264632, 0.58420532723898336, 0.581942987580589, 0.5711168715697603, 0.5375462388069019
Average of F-measure : 0.5334357745715175
Conditional Entropy : 0.696934977676099576, 1.0803037647145712, 1.06864693693958021, 1.1576038989993216, 1.3098320714206722
Average of Conditional Entropy : 1.0626646564402649
K = 11
F measure : 0.34185959330104354, 0.5278610693834248, 0.5267035376379128, 0.5216134953778978, 0.4893143810864078
Average of F-measure : 0.483104153573374
Conditional Entropy : 0.5687656398926776, 0.9258926953616672, 0.9153722473519796, 0.9926117180725632, 1.1513912348967166
Average of Conditional Entropy : 0.910240587115801
K = 11
F measure : 0.3102817014998313, 0.47566817821362833, 0.47402160420416256, 0.4621885689414235, 0.42776699414867965
Average of F-measure : 0.42996599887971215
Conditional Entropy : 0.5262923253147349, 0.8502859423866995, 0.8358485632780555, 0.9052592891394643, 1.062502389328589
Average of Conditional Entropy : 0.8360377018895087

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Step 4:Big Picture



F measure (K means) : 0.4196174072295201, 0.4107258552890226, 0.38507943166322833, 0.3693134601231837, 0.3695165518532498

Average of F-measure (K means) : 0.39085054123164087

Conditional Entropy (K means) : 2.4315195164099794, 1.6105272626903904, 2.3901311889119223, 1.4823478403550818, 2.2062877442740936

Average of Conditional Entropy (K means) : 2.0241627105282936

/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_spectral_embedding.py:261: UserWarning: Graph is not fully connected, spectral embedding may not work as expected.

"Graph is not fully connected, spectral embedding may not work as expected."

[0 0 0 ... 0 0 0]

F measure (Normalized Cut) : 0.12426006367001788, 0.16221799011989252, 0.12334623506380651, 0.1713202032045494, 0.1251109038688197

Average of F-measure (Normalized Cut) : 0.1412510791854172

Conditional Entropy (Normalized Cut) : 2.981458292939957, 1.9559806874633372, 2.8442489070919015, 1.7762458509224133, 2.6229656427962476

Average of Conditional Entropy (Normalized Cut) : 2.4361798762427713



F measure (K means) : 0.33959230073417923, 0.31947880020959796, 0.40492552384260455, 0.3462938251823974

Average of F-measure (K means) : 0.35257261249219474

Conditional Entropy (K means) : 3.420550142329566, 2.7488947817787928, 2.1133388257805867, 2.9821869703214885

Average of Conditional Entropy (K means) : 2.816242680052609

/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_spectral_embedding.py:261: UserWarning: Graph is not fully connected, spectral embedding may not work as expected.

"Graph is not fully connected, spectral embedding may not work as expected."

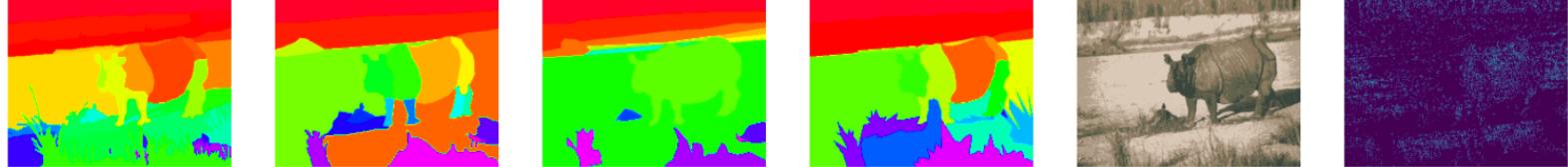
[0 0 0 ... 0 0 0]

F measure (Normalized Cut) : 0.08337772787071056, 0.09427152728267205, 0.14001499680868496, 0.09661483538362356

Average of F-measure (Normalized Cut) : 0.10356977183642277

Conditional Entropy (Normalized Cut) : 4.092409614811058, 3.227291223412986, 2.5306069208744044, 3.462324810562707

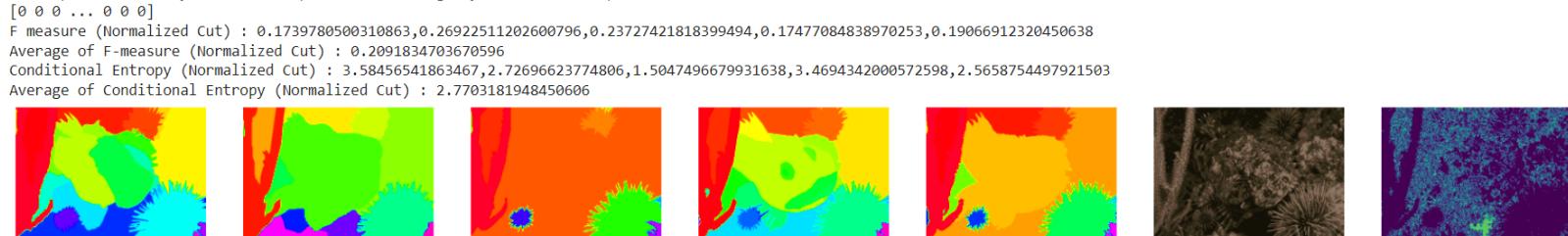
Average of Conditional Entropy (Normalized Cut) : 3.328158142415289



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F measure (K means) : 0.29078529819967447,0.24555729936788234,0.30362132668675545,0.2932182692331114,0.2559495185993287
Average of F-measure (K means) : 0.2778263424173505
Conditional Entropy (K means) : 3.3430745216289273,2.575777143514526,1.4418641579553535,3.285541675357306,2.4496919790583074
Average of Conditional Entropy (K means) : 2.619189895502884
/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_spectral_embedding.py:261: UserWarning: Graph is not fully connected, spectral embedding may not work as expected.
  "Graph is not fully connected, spectral embedding may not work as expected."
[0 0 0 ... 0 0 0]

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F measure (K means) : 0.567611584632278,0.5862046651892295,0.5619924939082444,0.5546298944136362,0.5856298155302041
Average of F-measure (K means) : 0.5712136907347184
Conditional Entropy (K means) : 1.0492580139488237,0.9539316029724454,1.0292637729220515,1.251617044922094,1.0137440701651037
Average of Conditional Entropy (K means) : 1.059562900861036
/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_spectral_embedding.py:261: UserWarning: Graph is not fully connected, spectral embedding may not work as expected.
  "Graph is not fully connected, spectral embedding may not work as expected."
F measure (Normalized Cut) : 0.1739780500310863,0.26922511202600796,0.23727421818399494,0.17477084838970253,0.19066912320450638
Average of F-measure (Normalized Cut) : 0.2091834703670596
Conditional Entropy (Normalized Cut) : 3.58456541863467,2.72696623774806,1.5047496679931638,3.4694342000572598,2.5658754497921503
Average of Conditional Entropy (Normalized Cut) : 2.7703181948450606

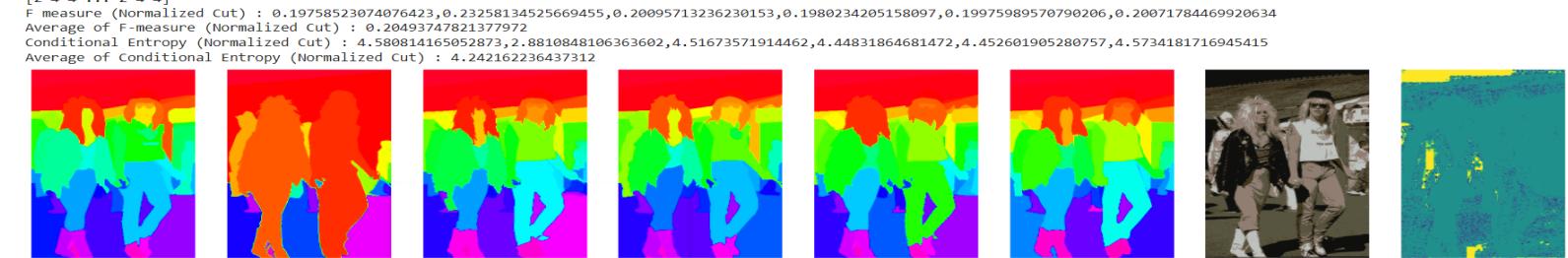
```



```

F measure (K means) : 0.37647992366825944,0.3490020497939924,0.38489583150078727,0.3735561804458466,0.39573955609042627,0.37715615740055003
Average of F-measure (K means) : 0.37613828314997694
Conditional Entropy (K means) : 3.868349761980524,2.573075342771381,3.7628607817487962,3.7615190346166054,3.694310040166436,3.8732301092189925
Average of Conditional Entropy (K means) : 3.588890845083789
/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_spectral_embedding.py:261: UserWarning: Graph is not fully connected, spectral embedding may not work as expected.
  "Graph is not fully connected, spectral embedding may not work as expected."
[2 4 4 ... 2 4 4]

```



- a) We notice that the k-means produces F-measure about 0.394 ,conditional entropy about 2.42 .
- b) We see that k-means gave better segmentations than normalized cut .

c) We see from the previous images that we got better F measure and better conditional entropy in k-means than in normalized cut .

Colab Link :

[Colab Link](#)

