CS5785 Homework 3

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Problem 1. Sentiment Analysis of Online Reviews.

(a) The labels are balanced (500 : 500 for each file). I read each file and process it line by line and put the data into a Pandas DataFrame (1000 rows). Then I concat the 3 DataFrames into one DataFrame (3000 rows) with hierarchical indexing (amazon, imdb and yelp).

(b) I picked all preprocessing strategies listed in the instruction and some other strategies I found at `https://machinelearningmastery.com/clean-text-machine-learning-python/`. The reasons are as follows.

- expand contractions
  This strategy simply performs replacement to contractions, such as I'm to I am, what's to what is and etc. This is very useful for dimensionality reduction.

- lowercase all of the words
  This strategy also reduces dimensionality, since we should treat the same word with different cases as the same entry in the word vector.

- strip punctuation
  Punctuation cannot clearly reflect the sentiment of a reviews. eg. "!" can be used in both positive and negative sentiment.

- strip numbers
  Numbers are not useful in sentiment analysis either.

- strip the stop words
  The stop words contain no meaning in English, so we can omit them to reduce the dimensionality of word vectors.

- stemming and lemmatization
  Stemming and lemmatization reduce each word to its base or root, which also reduce the dimensionality of word vectors. I use SnowballStemmer and WordNetLemmatizer in this problem.

(d) Each feature vectors has 3504 length, i.e. representing 3504 words. The first two reviews' feature vectors are as follows.

```
print training_set.iloc[0]
print training_set.iloc[1]
```

```
sentence                                  way plug u unless go convert
score                                                                0
feature_vector    [1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, ...
Name: 0, dtype: object
sentence              tie charger convers last minutesmajor problem
score                                                                0
feature_vector    [0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, ...
Name: 3, dtype: object
```

(e) I use log-normalization. First, I tried all 4 strategies and it performs best. Second, I find the reason to use log at http://onlinestatbook.com/2/transformations/log.html: "The log transformation can be used to make highly skewed distributions less skewed. This can be valuable both for making patterns in the data more interpretable and for helping to meet the assumptions of inferential statistics." Our word vectors are highly skewed distributed, as only a few words in each vector has positive values while others are 0. Thus, log-normalization works well for this problem. We thin TF-IDF may be a better choice for word vector normalization.

(f) The accuracy and confusion matrix for logistic regression are below.

```
Logistic Regression ACC: 0.8150
[[263  37]
 [ 74 226]]
```

The top 20 most important negative words are:

```
Negative top 20:
bad, -2.940010177795963
poor, -2.5000662875487514
worst, -2.1129273163378746
terribl, -1.9187343968442017
wast, -1.8419838593632043
slow, -1.69722945329617
suck, -1.652177338313711
aw, -1.6272464373236337
disappoint, -1.6269823601582507
horribl, -1.4969783123327889
stupid, -1.4604472244941435
start, -1.4338083724143165
bland, -1.4196933573475197
fail, -1.3418801400134233
piec, -1.341395709404752
plot, -1.3377730434028574
rude, -1.3156337005568535
avoid, -1.2928377131075706
hear, -1.2855568225651768
hate, -1.2530753973876092
```

The top 20 most important positive words are:

```
Positive top 20:
great, 3.728217853875945
love, 3.1307304894746175
excel, 2.543477888360755
delici, 2.3579199440102383
nice, 2.2610563814106817
amaz, 2.1328363185656607
fantast, 2.0145059778780205
beauti, 1.9685936229207004
awesom, 1.9095860263657145
best, 1.887332235856134
good, 1.8841164784088518
perfect, 1.7982309244889034
comfort, 1.7010272166626892
wonder, 1.5434490656079216
well, 1.5178364156388924
happi, 1.4414300528592643
incred, 1.4282204915691472
fine, 1.3881251478268803
funni, 1.3345018176751962
sturdi, 1.3205563559302762
```

Naive Bayes accuracy and confusion matrix.

```
Gaussian Naive Bayes ACC: 0.6317
[[268  32]
 [189 111]]
Bernoulli Naive Bayes ACC: 0.8050
[[252  48]
 [ 69 231]]
```

The accuracy and confusion matrix above shows that Logistic Regression and Bernoulli Naive Bayes perform better (ACC is larger than 0.8).

(g) Each feature vectors has 10798 length, i.e. representing 10798 words. The first two reviews' feature vectors are as follows.

```
print training_set.iloc[0]
print training_set.iloc[1]
```

```
sentence                                        way plug u unless go convert
score                                                                      0
feature_vector           [0.69314718056, 0.69314718056, 0.69314718056, ...
2_gram_feature_vector    [1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ...
Name: 0, dtype: object
sentence                     tie charger convers last minutesmajor problem
score                                                                      0
feature_vector           [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.69314718056, ...
2_gram_feature_vector    [0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, ...
Name: 3, dtype: object
```

I use log-normalization, too, with the same reason above.

The accuracy and confusion matrix for logistic regression are below.

```
Logistic Regression ACC: 0.6433
[[271  29]
 [185 115]]
```

The top 20 most important negative words are:

```
Negative top 20:
wast time, -1.6266337663157204
wast money, -1.2108755181402313
custom servic, -0.885446698216792
poor qualiti, -0.8081575997816369
stay away, -0.80332538188543
piec junk, -0.7777574898399167
worst ever, -0.7631486261640384
bad film, -0.7557103236968924
realli bad, -0.7313689428304294
wait wait, -0.7110396622789038
good way, -0.7076382278339408
make mistak, -0.7071255012510449
buy product, -0.7048544951320117
ever go, -0.6881550537396549
zero star, -0.6663238958811999
act bad, -0.6662888020728832
go back, -0.6625560941137096
anytim soon, -0.6614309848132359
look good, -0.6601001979350706
send back, -0.6530665613641474
```

The top 20 most important positive words are:

```
Positive top 20:
work great, 2.054405466821827
high recommend, 1.7524930364450328
one best, 1.4582411255582608
great phone, 1.289089164994326
great product, 1.1872160667930691
food good, 1.0734850744325828
realli good, 1.0679433092586532
easi use, 1.009555329850475
great food, 0.9843961434373667
reason price, 0.9029096380166195
food delici, 0.8999181388557159
good price, 0.8854444828109942
great servic, 0.8851646225386762
love place, 0.8686200339604135
work fine, 0.835652593585165
pretti good, 0.8017189465143757
well made, 0.7951033012950273
great film, 0.7902639845663137
good product, 0.7767482726210645
great place, 0.776207877651663
```

Naive Bayes accuracy and confusion matrix.

```
Gaussian Naive Bayes ACC: 0.6300
[[282  18]
 [204  96]]
Bernoulli Naive Bayes ACC: 0.6400
[[273  27]
 [189 111]]
```

The accuracy and confusion matrix above shows that Logistic Regression and Naive Bayes have similar performance.

(h) We implement the PCA using basic matrix operations. The results are listed below.
(1) 1-gram
The accuracy and confusion matrix for logistic regression are below (reduce the dimension of features to 10, 50 and 100, respectively.)

```
Logistic Regression ACC: 0.5867
[[255  45]
 [203  97]]
Logistic Regression ACC: 0.6983
[[253  47]
 [134 166]]
Logistic Regression ACC: 0.7333
[[250  50]
 [110 190]]
```

The accuracy and confusion matrix for Naive Bayes are below (reduce the dimension of features to 10, 50 and 100, respectively.)

```
Gaussian Naive Bayes ACC: 0.5650
[[188 112]
 [149 151]]
Bernoulli Naive Bayes ACC: 0.5650
[[188 112]
 [149 151]]
Gaussian Naive Bayes ACC: 0.6233
[[190 110]
 [116 184]]
Bernoulli Naive Bayes ACC: 0.6233
[[190 110]
 [116 184]]
Gaussian Naive Bayes ACC: 0.6650
[[210  90]
 [111 189]]
Bernoulli Naive Bayes ACC: 0.6650
[[210  90]
 [111 189]]
```

(2) 2-gram The accuracy and confusion matrix for logistic regression are below (reduce the dimension of features to 10, 50 and 100, respectively.)

```
Logistic Regression ACC: 0.5050
[[297   3]
 [294   6]]
Logistic Regression ACC: 0.5267
[[292   8]
 [276  24]]
Logistic Regression ACC: 0.5367
[[286  14]
 [264  36]]
```

The accuracy and confusion matrix for Naive Bayes are below (reduce the dimension of features to 10, 50 and 100, respectively.)

```
Gaussian Naive Bayes ACC: 0.5033
[[292   8]
 [290  10]]
Bernoulli Naive Bayes ACC: 0.5033
[[292   8]
 [290  10]]
Gaussian Naive Bayes ACC: 0.5150
[[264  36]
 [255  45]]
Bernoulli Naive Bayes ACC: 0.5150
[[264  36]
 [255  45]]
Gaussian Naive Bayes ACC: 0.5283
[[255  45]
 [238  62]]
Bernoulli Naive Bayes ACC: 0.5283
[[255  45]
 [238  62]]
```

The accuracy and confusion matrix above shows that using PCA may lose some accuracy, i.e. more dimension reduce, more loss. But when we reduce the dimension to 100, the performance is good enough. So sometimes we need to make a trade-off between computing resources and performance, to determine whether to use PCA. We can also find that 2-gram still performs worse than 1-gram.

(i) The bag of words performs best in the task, because it does not reduce any information like PCA and sentiment in reviews is more likely to be reflected by single words rather than 2-grams. People prefer to use single word to express their attitude and sentiment in online reviews, because online reviews are usually extremely short and the words in them

express sentiment with high efficiency.

Problem 2. Clustering for Text Analysis..

(a) doc-word
We use Elbow method to find the best k, but the figure does not have an obvious "elbow". We choose 8 as k.
The top 10 words in each cluster are as follows.

cluster 0:
- residues
- crystal
- binding
- conserved
- side
- helix
- loop
- chains
- residue
- structural

cluster 1:
- says
- researchers
- fig
- scientists
- year
- just
- get
- people
- last
- usa

cluster 2:
- protein
- gene
- proteins
- cell
- sequence
- genes
- dna
- cells
- amino

sequences

cluster 3:
cells
expression
cell
protein
mice
expressed
antibody
mouse
induced
expressing

cluster 4:
energy
electron
fig
density
shows
temperature
structure
human
measured
constant

cluster 5:
responses
response
neurons
stimuli
visual
significant
stimulus
fig
test
cortex

cluster 6:
fig
mail
shown
reports
observed
function

correspondence
start
analysis
addressed

cluster 7:
values
global
north
estimates
estimate
surface
years
variations
lower
period

The top 10 documents closest to each cluster center are as follows.

cluster 0:
Structure of Yeast Poly(A) Polymerase Alone and in Complex with 3'-dATP
Structure of Murine CTLA-4 and Its Role in Modulating T Cell Responsiveness
Structure of the S15,S6,S18-rRNA Complex: Assembly of the 30S Ribosome Central Domain
Atomic Structure of PDE4: Insights into Phosphodiesterase Mechanism and Specificity
Twists in Catalysis: Alternating Conformations of Escherichia coli Thioredoxin Reductase
The Productive Conformation of Arachidonic Acid Bound to Prostaglandin Synthase
Redox Signaling in Chloroplasts: Cleavage of Disulfides by an Iron-Sulfur Cluster
Convergent Solutions to Binding at a Protein-Protein Interface
Structural Basis of Smad2 Recognition by the Smad Anchor for Receptor Activation
Structure of the Protease Domain of Memapsin 2 (b-Secretase) Complexed with Inhibitor

cluster 1:
Information Technology Takes a Different Tack
Science Survives in Breakthrough States
Vaccine Studies Stymied by Shortage of Animals
For 'Father' of Abortion Drug, Vindication at Last
On a Slippery Slope to Mediocrity?
In Europe, Hooligans Are Prime Subjects for Research
Japan's Whaling Program Carries Heavy Baggage
Is AIDS in Africa a Distinct Disease?
New Science Chief Must Juggle Missions and Politics

Building a Disease-Fighting Mosquito

cluster 2:

Requirement of NAD and SIR2 for Life-Span Extension by Calorie Restriction in Saccharomyces Cerevisiae

Suppression of Mutations in Mitochondrial DNA by tRNAs Imported from the Cytoplasm

Distinct Classes of Yeast Promoters Revealed by Differential TAF Recruitment

Ubiquitination: More Than Two to Tango

Efficient Initiation of HCV RNA Replication in Cell Culture

New Insights into an Old Modification

Negative Regulation of the SHATTERPROOF Genes by FRUITFULL during Arabidopsis Fruit Development

Reading the Worm Genome

Active Remodeling of Somatic Nuclei in Egg Cytoplasm by the Nucleosomal ATPase ISWI

Cloning and Heterologous Expression of the Epothilone Gene Cluster

cluster 3:

T Cell-Independent Rescue of B Lymphocytes from Peripheral Immune Tolerance

Reduced Food Intake and Body Weight in Mice Treated with Fatty Acid Synthase Inhibitors

Coupling of Stress in the ER to Activation of JNK Protein Kinases by Transmembrane Protein Kinase IRE1

Patterning of the Zebrafish Retina by a Wave of Sonic Hedgehog Activity

An Anti-Apoptotic Role for the p53 Family Member, p73, during Developmental Neuron Death

Impaired Prion Replication in Spleens of Mice Lacking Functional Follicular Dendritic Cells

Requirement of the RNA Editing Deaminase ADAR1 Gene for Embryonic Erythropoiesis

CD95/CD95 Ligand Interactions on Epithelial Cells in Host Defense to Pseudomonas aeruginosa

Severely Reduced Female Fertility in CD9-Deficient Mice

Regulation of B Lymphocyte and Macrophage Development by Graded Expression of PU.1

cluster 4:

Ambipolar Pentacene Field-Effect Transistors and Inverters

A Stable Bicyclic Compound with Two Si=Si Double Bonds

A Cyclic Carbanionic Valence Isomer of a Carbocation: Diphosphino Analogs of Diaminocarbocations

Graphical Evolution of the Arnold Web: From Order to Chaos

High-Gain Harmonic-Generation Free-Electron Laser

Prospects for the Polymer Nanoengineer

Viscosity Mechanisms in Accretion Disks

Mechanisms of Ordering in Striped Patterns

Anomalous Polarization Profiles in Sunspots: Possible Origin of Umbral Flashes
A Light-Emitting Field-Effect Transistor

cluster 5:
Cholinergic Synaptic Inhibition of Inner Hair Cells in the Neonatal Mammalian Cochlea
Selectivity for 3D Shape That Reveals Distinct Areas within Macaque Inferior Temporal Cortex
Mirror-Image Confusion in Single Neurons of the Macaque Inferotemporal Cortex
Abolition and Reversal of Strain Differences in Behavioral Responses to Drugs of Abuse after a Brief Experience
Reversal of Antipsychotic-Induced Working Memory Deficits by Short-Term Dopamine D1 Receptor Stimulation
Language Discrimination by Human Newborns and by Cotton-Top Tamarin Monkeys
Modulation of Human Visual Cortex by Crossmodal Spatial Attention
Necessity for Afferent Activity to Maintain Eye-Specific Segregation in Ferret Lateral Geniculate Nucleus
Control of SIV Rebound through Structured Treatment Interruptions during Early Infection
Evidence for Brainstem Structures Participating in Oculomotor Integration

cluster 6:
Algorithmic Gladiators Vie for Digital Glory
Reopening the Darkest Chapter in German Science
National Academy of Sciences Elects New Members
Corrections and Clarifications: Unearthing Monuments of the Yarmukians
Corrections and Clarifications: Charon's First Detailed Spectra Hold Many Surprises
Corrections and Clarifications: A Short Fe-Fe Distance in Peroxodiferric Ferritin: Control of Fe Substrate versus Cofactor Decay?
Heretical Idea Faces Its Sternest Test
Archaeology in the Holy Land
Corrections and Clarifications: Uninterrupted MCM2-7 Function Required for DNA Replication Fork Progression
Corrections and Clarifications: A Nuclear Solution to Climatic Change?

cluster 7:
Reconstruction of the Amazon Basin Effective Moisture Availability over the past 14,000 Years
Greenland Ice Sheet: High-Elevation Balance and Peripheral Thinning
Isotopic Evidence for Variations in the Marine Calcium Cycle over the Cenozoic
Mass Balance of the Greenland Ice Sheet at High Elevations
Rapid Kimberlite Ascent and the Significance of Ar-Ar Ages in Xenolith Phlogopites
Glacial Climate Instability
The Role of the Southern Ocean in Uptake and Storage of Anthropogenic Carbon Dioxide
Remobilization in the Cratonic Lithosphere Recorded in Polycrystalline Diamond
Accretion of Primitive Planetesimals: Hf-W Isotopic Evidence from Enstatite Chondrites

Temporal Trends in Deep Ocean Redfield Ratios

The algorithm captured the themes of documents, and clustered them into different categories according to their subjects, such as biology, geography and history. This algorithm can be used to classify articles into different categories based on their contents and subjects.

(b) word-doc
We use Elbow method to find the best k. We choose 9 as k.
The top 10 titles in each cluster are as follows.

cluster 0:

Regulated Cleavage of a Contact-Mediated Axon Repellent

Noxa, a BH3-Only Member of the Bcl-2 Family and Candidate Mediator of p53-Induced Apoptosis

Positional Syntenic Cloning and Functional Characterization of the Mammalian Circadian Mutation tau

Signaling and Circuitry of Multiple MAPK Pathways Revealed by a Matrix of Global Gene Expression Profiles

Interacting Molecular Loops in the Mammalian Circadian Clock

Cross Talk between Interferon-g and -a/b Signaling Components in Caveolar Membrane Domains

Regulation of STAT3 by Direct Binding to the Rac1 GTPase

Function of PI3Kg in Thymocyte Development, T Cell Activation, and Neutrophil Migration

Central Role for G Protein-Coupled Phosphoinositide 3-Kinase g in Inflammation

Protein Interaction Mapping in C. elegans Using Proteins Involved in Vulval Development

cluster 1:

Status and Improvements of Coupled General Circulation Models

Sedimentary Rocks of Early Mars

Climate Extremes: Observations, Modeling, and Impacts

A 22,000-Year Record of Monsoonal Precipitation from Northern Chile's Atacama Desert

Internal Structure and Early Thermal Evolution of Mars from Mars Global Surveyor Topography and Gravity

Coherent High- and Low-Latitude Climate Variability during the Holocene Warm Period

Rapid Changes in the Hydrologic Cycle of the Tropical Atlantic during the Last Glacial

Climate Impact of Late Quaternary Equatorial Pacific Sea Surface Temperature Variations

The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System

Causes of Climate Change over the past 1000 Years

cluster 2:

Advances in the Physics of High-Temperature Superconductivity

Quantum Criticality: Competing Ground States in Low Dimensions

The Atom-Cavity Microscope: Single Atoms Bound in Orbit by Single Photons

Orbital Physics in Transition-Metal Oxides
Negative Poisson's Ratios for Extreme States of Matter
Generating Solitons by Phase Engineering of a Bose-Einstein Condensate
Self-Mode-Locking of Quantum Cascade Lasers with Giant Ultrafast Optical Nonlinearities
NEAR at Eros: Imaging and Spectral Results
Blue-Fluorescent Antibodies
The Galactic Center: An Interacting System of Unusual Sources

cluster 3:
Positional Syntenic Cloning and Functional Characterization of the Mammalian Circadian Mutation tau
The Genome Sequence of Drosophila melanogaster
Kinesin Superfamily Motor Protein KIF17 and mLin-10 in NMDA Receptor-Containing Vesicle Transport
Noxa, a BH3-Only Member of the Bcl-2 Family and Candidate Mediator of p53-Induced Apoptosis
Crystal Structure of the Ribonucleoprotein Core of the Signal Recognition Particle
Pol k: A DNA Polymerase Required for Sister Chromatid Cohesion
Integration of Multiple Signals through Cooperative Regulation of the N-WASP-Arp2/3 Complex
Role of the Mouse ank Gene in Control of Tissue Calcification and Arthritis
Regulated Cleavage of a Contact-Mediated Axon Repellent
Comparative Genomics of the Eukaryotes

cluster 4:
A Mouse Chronology
Meltdown on Long Island
Presidential Forum: Gore and Bush Offer Their Views on Science
Silent No Longer: 'Model Minority' Mobilizes
Atom-Scale Research Gets Real
The Rise of the Mouse, Biomedicine's Model Mammal
Ecologists on a Mission to Save the World
Infectious History
Help Needed to Rebuild Science in Yugoslavia
I'd like to See America Used as a Global Lab

cluster 5:
NEAR at Eros: Imaging and Spectral Results
Reduction of Tropical Cloudiness by Soot
The Atom-Cavity Microscope: Single Atoms Bound in Orbit by Single Photons
Rocks from the Mantle Transition Zone: Majorite-Bearing Xenoliths from Malaita, Southwest Pacific
Climate Impact of Late Quaternary Equatorial Pacific Sea Surface Temperature Variations

Climate Extremes: Observations, Modeling, and Impacts
Causes of Climate Change over the past 1000 Years
Experiments and Simulations of Ion-Enhanced Interfacial Chemistry on Aqueous NaCl Aerosols
Advances in the Physics of High-Temperature Superconductivity
Internal Structure and Early Thermal Evolution of Mars from Mars Global Surveyor Topography and Gravity

cluster 6:
A Mouse Chronology
Atom-Scale Research Gets Real
The Genome Sequence of Drosophila melanogaster
Breakthrough of the Year: Genomics Comes of Age
Presidential Forum: Gore and Bush Offer Their Views on Science
Infectious History
Positional Syntenic Cloning and Functional Characterization of the Mammalian Circadian Mutation tau
Comparative Genomics of the Eukaryotes
Status and Improvements of Coupled General Circulation Models
Meltdown on Long Island

cluster 7:
Inhibition of Experimental Liver Cirrhosis in Mice by Telomerase Gene Delivery
Translating Stem and Progenitor Cell Biology to the Clinic: Barriers and Opportunities
Function of PI3Kg in Thymocyte Development, T Cell Activation, and Neutrophil Migration
An Oral Vaccine against NMDAR1 with Efficacy in Experimental Stroke and Epilepsy
Central Role for G Protein-Coupled Phosphoinositide 3-Kinase g in Inflammation
Requirement for RORg in Thymocyte Survival and Lymphoid Organ Development
Therapeutic Approaches to Bone Diseases
Mammalian Neural Stem Cells
Prostaglandin ¡latex¿D_2¡/latex¿ as a Mediator of Allergic Asthma
Bone Resorption by Osteoclasts

cluster 8:
Help Needed to Rebuild Science in Yugoslavia
Atom-Scale Research Gets Real
A Mouse Chronology
Meltdown on Long Island
Silent No Longer: 'Model Minority' Mobilizes
I'd like to See America Used as a Global Lab
Clones: A Hard Act to Follow
Ecologists on a Mission to Save the World
Soft Money's Hard Realities

Lee's Special Status Fuels Academy's Rising Reputation

The top 10 words closest to each cluster center are as follows:

cluster 0:
kinase
promoter
polymerase
staining
pcr
mrna
vivo
regulated
assay
signaling

cluster 1:
decadal
holocene
anomaly
sst
basins
tropics
equator
sedimentary
lunar
silicate

cluster 2:
resonant
anisotropic
fermi
crystallographic
reflections
tunneling
metallic
lying
transverse
incident

cluster 3:
triton
methionine
glutathione

agarose
isoforms
glycerol
histidine
cys
subcellular
glycine

cluster 4:
celera
intelligence
managers
income
schools
math
weapons
capital
court
draft

cluster 5:
start
gray
decrease
error
peak
res
magnitude
fraction
rev
maximum

cluster 6:
aptamers
lcts
dnag
trxr
neas
doxy
proteorhodopsin
lg268
nompc
rory

cluster 7:

lymphoid
immunoreactivity
injury
transplantation
cd8
abnormalities
littermates
hematopoietic
systemic
inflammatory

cluster 8:
researcher
didnt
doesnt
hopes
got
plans
getting
biologist
cant
theres

The algorithm captured the meanings of words, and clustered them into different categories according to the subjects the words belong to, such as biology, geography and history. This algorithm can be used to classify words into different categories based on their meanings.

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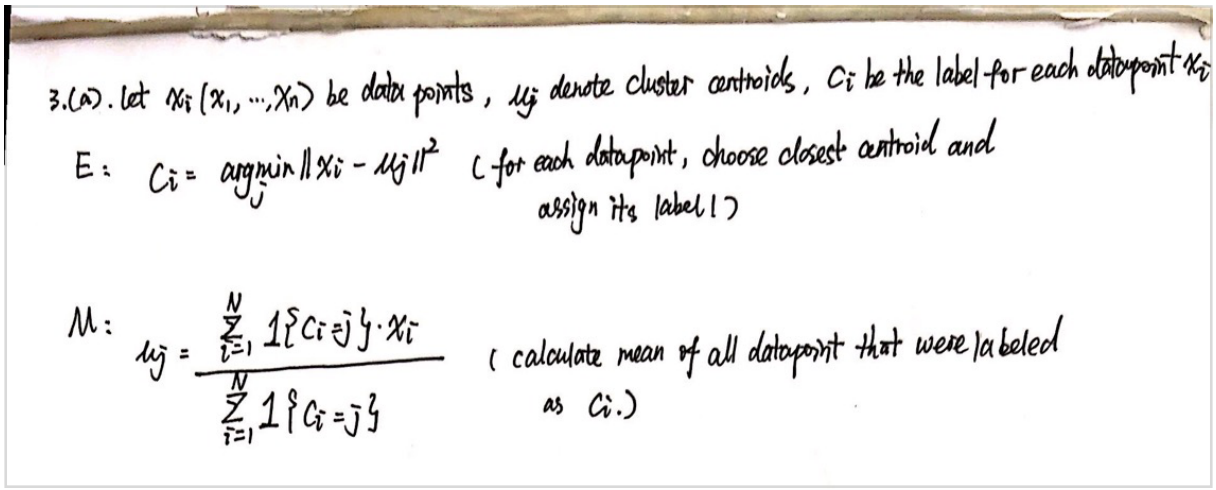
3.(a)

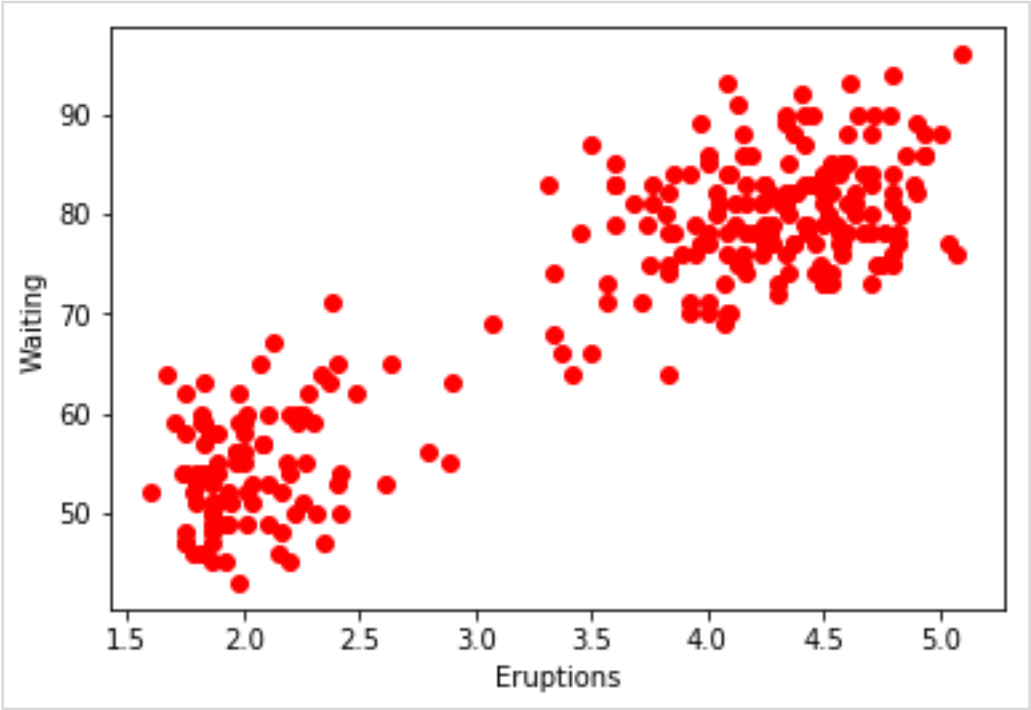
k means can also be viewed as a special case of EM algorithm, but it assumes clusters are spherical distributed.

- E step: given computed centroids(means), assign each data point label according to the closest centroid class.
- M step: given the newly assigned label, compute the new centroid(mean) for each class.



3.(b)

parse the data and plot all points on 2D plane.

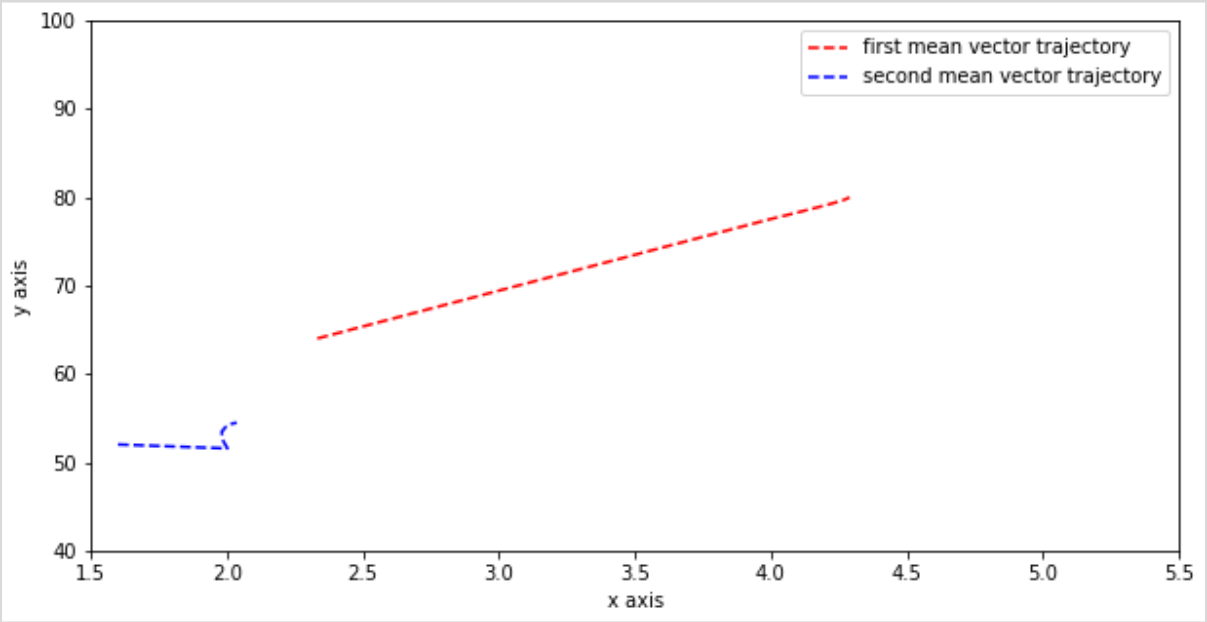


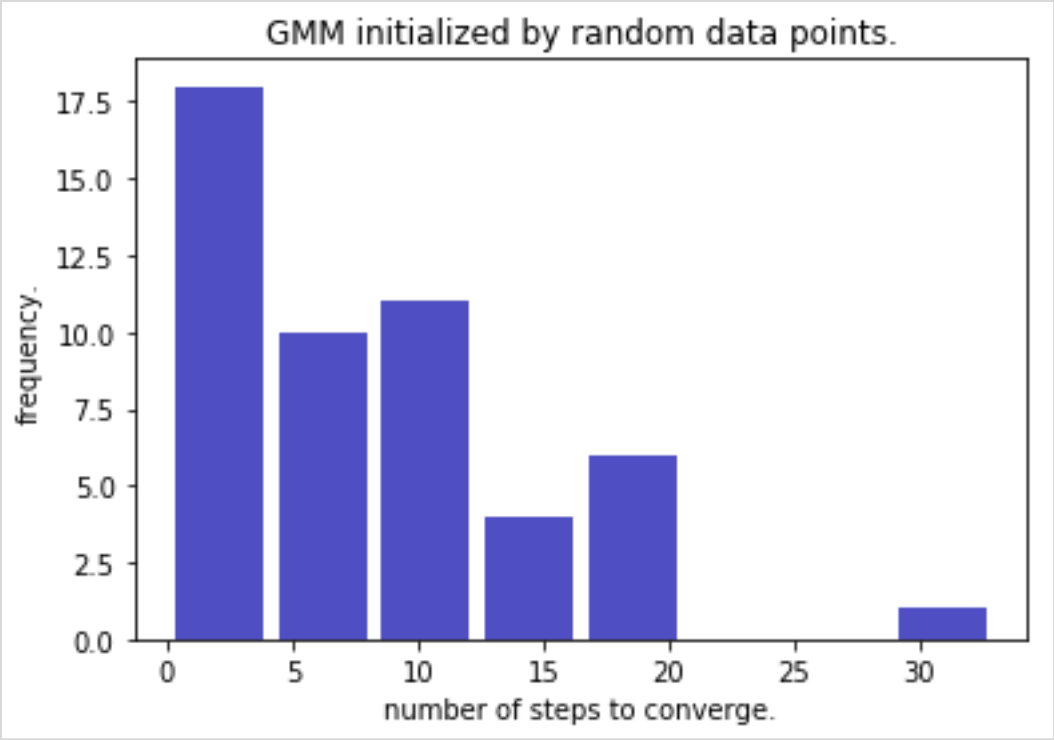
3.(c)

We implement GMM by ourselves. there are several assumptions we make:

- initial mu in Gaussian distribution is initialized by randomly choosing from existing datapoint.
- initial sigmas in Gaussian distribution is initialized by randomly sampling from (1, 6).

The below graph shows the means vector trajectory for a single random initialization.



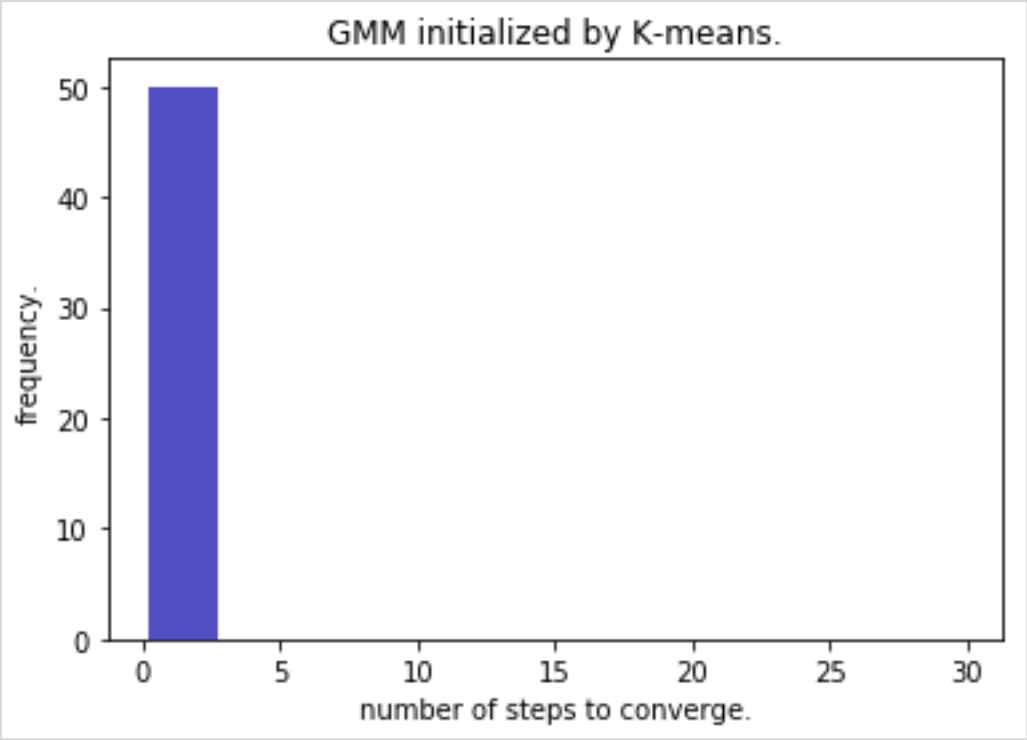


3.(d)

```
# new mean by maxmimum likelihood estimation on K-means.
[array([ 4.29793023, 80.28488372]), array([ 2.09433, 54.75   ])]


# new variance by maxmimum likelihood estimation on K-means.
[array([[ 0.17761717,  0.76310127],
       [ 0.76310127, 31.48279475]]),
 array([[ 0.1542787,  0.9856625],
       [ 0.9856625, 34.4075   ]])]
```

we can see the performance of initialization using k-means is way better than the random initialization as it takes less iterations to converge.



4.(a) i

assumptions:

- We assume that we can use euclidean distances to approximate Nei's distance.
- We assume that m dimensions yielded by MDS are suffice to simulate the original data relations.
- We also assume that the positions(coordinates) of the MDS-transformed points are't related to its original meaning, as it is subject to rotation, translation and reflection and therefore are not unique.

circumstances that it could fail:

When the original data are in a high dimensional space, reducing them into 2-dimensional space with MDS may not be able to correctly represent their original structure.

how could be measure:

We can measure the total information loss by measuring the sum difference between the predicted distances and their original distances.

total loss = np.linalg.norm(D - D') / np.linalg.norm(D)

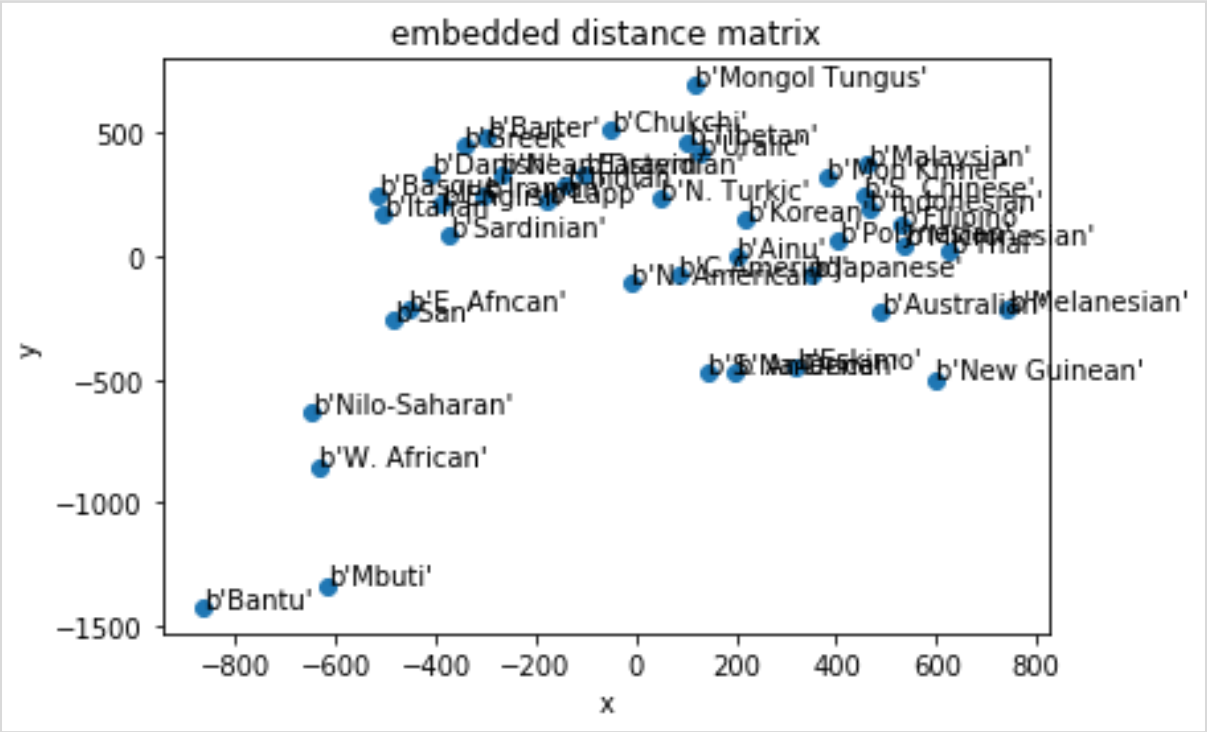
where D represents the original dissimilarity matrix, and D' represents the computed distance matrix, where each entry represents the euclidean distance between two objects

after MDS transformation.

4.(a) ii.

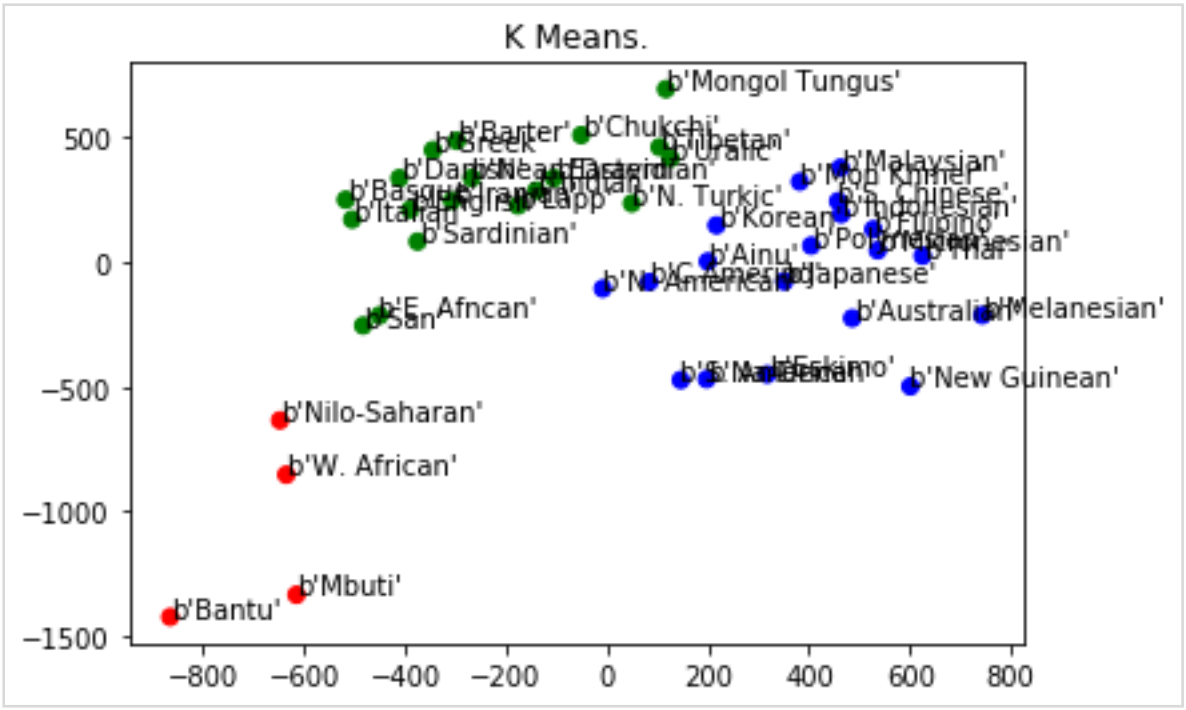
By sorting the singular value of D in descending order, and pick a number of top singular values that would explain the most of the total variance, such as the 95% of the variance. The number of singular values being picked is the desired dimension we want to reduce to.

4.(a) iii



4.(b)

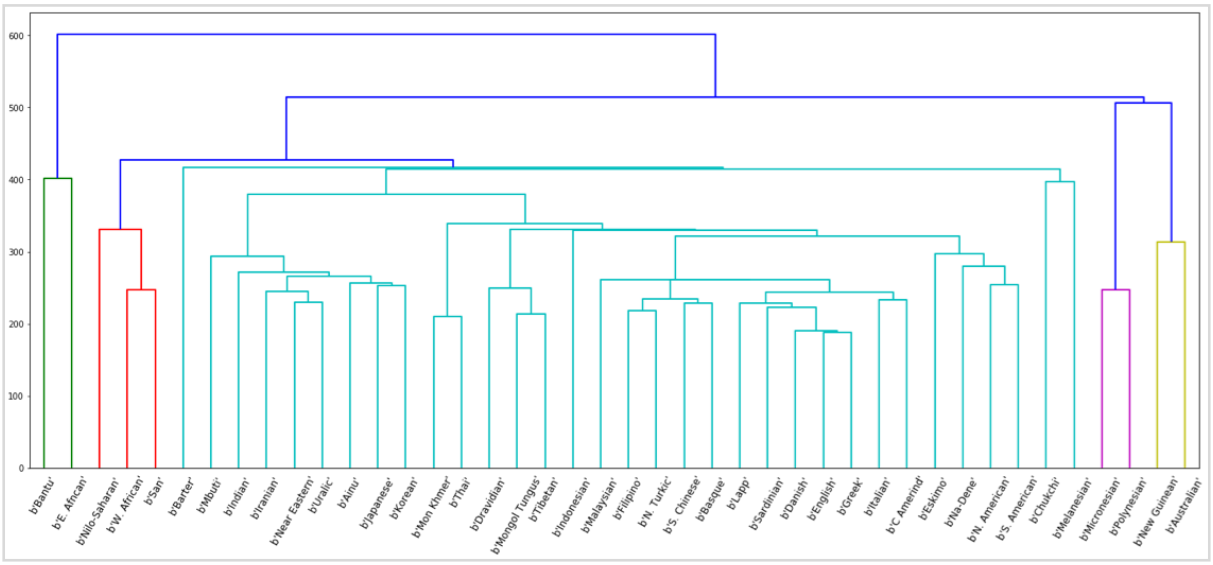
we choose K = 3.

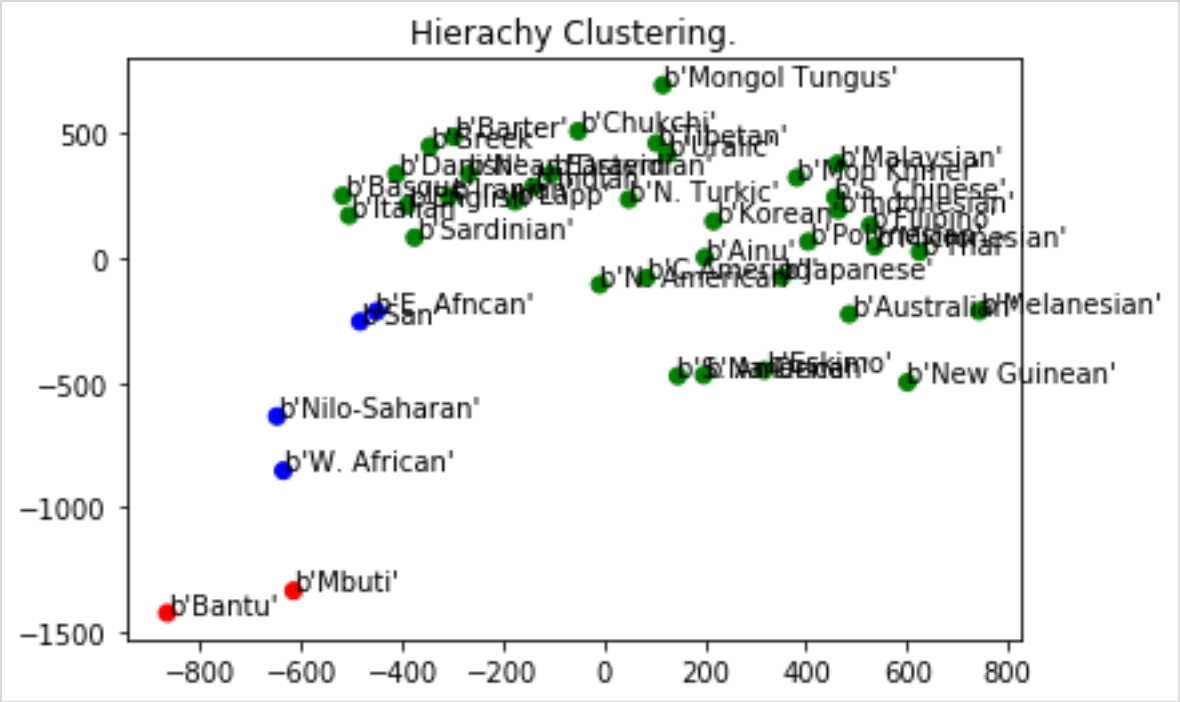


I do not agree with the resulting clustering. Some cultural, political information are lost during the process of MDS into 2 dimensions.

As we can also see from the original disimilarity map where Afncan and Saharan have a low dissimilarity score which means they are more similar than with other points. However, in the resulting clustering, it classifies them into two different groups. As K-means performs on comparing euclidean distances with hard threshold, it provides little explanations on the data points that lie on the edge of decision boundary.

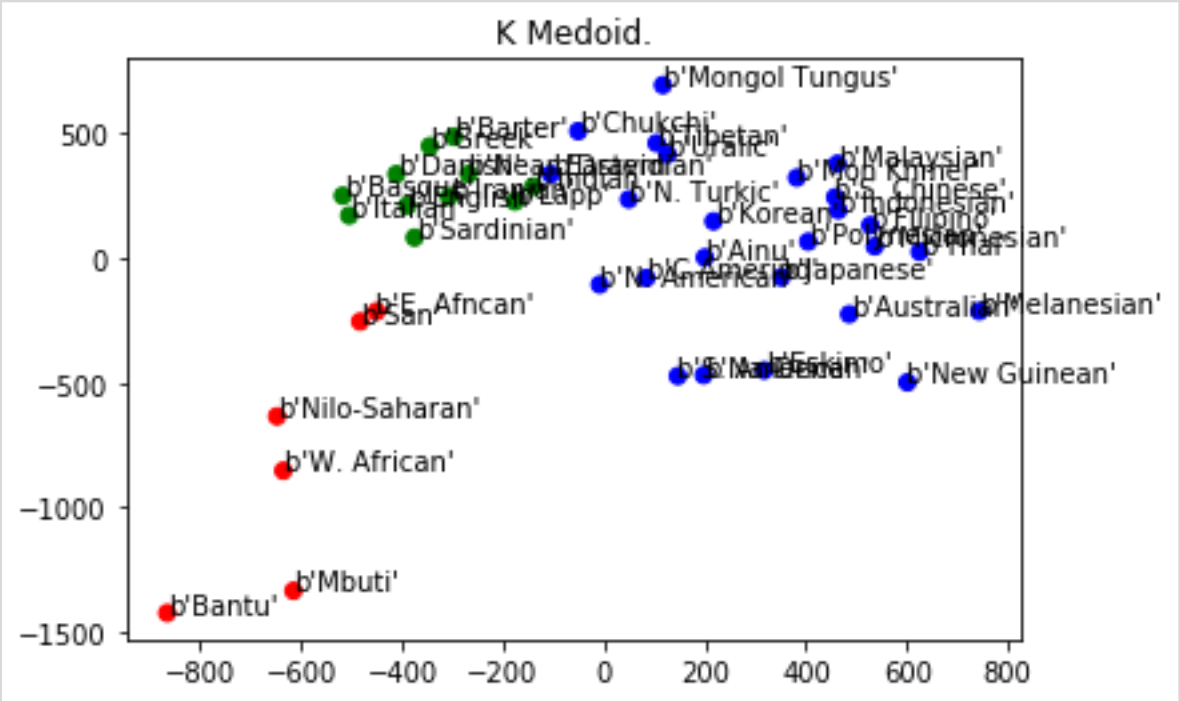
4.(c)





the clustering result I obtain using hierarchy clustering performs worse than the k-means algorithm.

4.(d)



From observation, there is no significant difference between the clusters generated by K-means and K-medoids.