VIRGINIA COMMONWEALTH UNIVERSITY

Statistical analysis and modelling (SCMA 632)

A4a: Multivariate Analysis and Business Analytics Applications: Principal Component Analysis and Factor Analysis

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CONTENTS

Introduction

This study aims to use PCA and FA on a survey dataset to uncover the fundamental characteristics of the data, simplify the dataset, emphasize important patterns, and reveal hidden aspects. Data analysis is crucial for extracting significant insights from a dataset. Principal Component Analysis (PCA) and Factor Analysis (FA) are two commonly used methods to minimize the intricacy of data while retaining as much information as possible. PCA converts original variables into a new collection of variables called principle components, which capture the majority of the variation found in the original dataset. This reduces the complexity of high-dimensional data while maintaining its fundamental qualities, making it a valuable tool for recognizing trends, spotting anomalies, and organizing data for future study. Factor Analysis (FA) is a statistical method used to identify underlying factors or dimensions in a set of observed variables. It aims to create a model representing observed variables using a smaller set of unobserved variables called factors. The main objective of factor analysis (FA) is to find the underlying constructs that influence the connections between observed variables, which is especially valuable in the study of surveys. This will enhance understanding of the data structure, guiding future data-driven decisions and initiatives.

Objectives

- Apply Principal Component Analysis (PCA) to simplify the survey dataset.
- Identify and interpret the principal components explaining the majority of the dataset's variance.
- Perform Factor Analysis (FA) to uncover underlying latent factors influencing respondents' answers.
- Compare and contrast the results from both techniques to understand the data structure.
- Discuss how findings from PCA and FA can inform data-driven decisions and research.

Business Significance

Principal Component Analysis (PCA) and Factor Analysis (FA) are valuable tools for businesses that help them understand complex datasets. They provide data-driven insights that can drive informed decision-making, resource allocation, market segmentation, and product development. PCA helps businesses identify key variables that influence customer behavior and employee satisfaction, enabling them to tailor their strategies more effectively. FA can inform product development by uncovering customer needs and preferences, enabling businesses to innovate and improve their products to meet market demands.

Risk management is another area of significance, with PCA aiding in developing predictive analytics to anticipate market trends, customer churn, and financial risks. Operational efficiency can be improved by understanding key operational drivers through FA, leading to cost savings and improved performance.

Strategic planning is another area of significance, with insights gained from PCA and FA supporting long-term strategies. They can help businesses identify industry trends and patterns, allowing them to adapt and stay competitive. Employee insights can also be used to enhance workforce productivity and retention.

Customer experience enhancement is another area of significance, with personalized services and improved customer support being key strategies. Feedback utilization can be used to turn qualitative data into quantitative insights, driving continuous improvement.

Competitive advantage is also gained through market positioning and innovation, as insights derived from these analyses can spur unique solutions and differentiate businesses from competitors. Overall, PCA and FA offer a robust framework for understanding complex datasets, driving growth, innovation, and long-term success.

Results and Interpretation using R

- **Performing PCA after converting categorical variables into dummy variables.**

```
# Convert categorical variables to dummy variables
> encoded_data <- dummy_cols(data, remove_first_dummy = TRUE, remove_se
lected_columns = TRUE)
>
# Remove constant or zero-variance columns
> encoded_data <- encoded_data[, apply(encoded_data, 2, function(col) l
ength(unique(col)) > 1)]
>
# Perform PCA (prcomp function is part of base stats package)
> pca <- prcomp(encoded_data, center = TRUE, scale. = TRUE)
>
# Print the results
> print(pca$x)
             PC1        PC2        PC3          PC4         PC5        
PC6         PC7
 [1,]  1.2125429  0.5391248 -2.2858715  1.9207616861 -0.76976465  1.839
84258 -2.11532365
 [2,]  3.8532873  0.8885635  1.2274429 -0.6600603199  0.68840531 -2.074
79342  1.68130572
 [3,]  3.8933570 -4.8035440  1.5638546 -4.6685526231 -0.85350984 -2.167
44057 -2.27635263
 [4,] -7.2827249  1.3053938 -3.0251846 -5.0930501741  3.25000159  1.618
99142  1.17216805
 [5,]  1.7516098  1.5948700 -0.9006248  1.8226842423 -0.49011263  1.150
31630 -2.32226973
 [6,]  1.5453953  2.0493328 -1.6860590 -0.0312708295 -1.69760595  0.207
21253  0.01393625
 [7,] -4.4532888 -2.6149083 -0.2997944  1.1024524178  3.05211979  1.487
60736 -1.14588016
 [8,]  5.5593254 -1.6783589  0.7175560 -2.0495742975 -2.63754351  2.002
03653  0.51756733
 [9,]  2.8068443  1.1535681 -1.8303381  1.0596668178 -3.73241850  1.614
80005  1.00045752
[10,] -3.0334659 -3.0958524  0.5033510 -3.0386212315 -1.53573672 -0.149
06830 -1.36563829
[11,]  3.9238831 -0.1884383  2.0596815  0.5661561866  3.47126033 -0.554
55159  0.71639199
[12,]  3.1383247  1.8828988  0.8587051  0.5522209941 -1.40436911 -1.993
21098  0.16146082
[13,]  3.6912819 -1.5588123  1.7372295 -0.4799654656  0.05300375  2.215
83446  0.05175781
[14,] -1.0203497 -3.1322780 -0.2586318  3.0298001137  1.12855828  0.540
02719 -3.09523131
                PC8         PC9          PC10        PC11        PC12        
PC13        PC14
 [1,]  3.8162668362 -0.45655102  0.4899561991 -2.09837964  0.50657228 -
2.00013821  1.03891665
 [2,]  4.2896942060 -5.70922769  2.9761110461 -2.07332710 -2.59655876  
1.91757530  0.38535252
 [3,]  0.1569159257 -0.60445799  1.6213585219  0.69667230  1.36869230  
2.13654378  1.37620468
 [4,] -0.1488809748 -0.83484206 -1.2806046975  1.55309431  0.31442406 -
0.70504103 -0.87135380
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```
 [5,] -1.1866673956 -2.93114764 -2.1999239648 -0.37312710  1.40534855 -
1.30123985 -2.75760776
 [6,] -1.2161122480 -0.46866919  2.0928880377  1.53211356  1.96519809 -
1.44290438  0.73406648
 [7,]  2.1321878086  0.09009111  1.6293714677  0.04346595  0.37939047 -
2.16869555 -0.66564179
 [8,]  2.0935509318  0.67501698 -0.3637991317 -1.52891199  0.72916669 -
0.71679422  0.72442448
 [9,] -2.1543726362 -2.48120709 -0.9726956986  0.38267228 -0.44353106 -
0.07908258 -1.72822357
[10,] -0.2019216186 -0.91642712  1.0126426755  2.63722840 -4.68607981 -
0.10315632  1.37072998
[11,]  0.0203528012  0.21937373 -0.4154018169 -1.15650419 -0.01691617 -
0.47675375 -0.42749584
[12,]  1.3165876020 -5.53758808  2.7976237868  3.06511936  0.47463133  
0.18657146 -1.27597712
[13,]  0.9715725989  0.84285640 -1.9938608973  0.69503037  2.64541193  
1.95271926  0.33328314
[14,]  3.5064381155 -0.08159396  0.1454949482  0.90033331 -0.42195753 -
1.50599915 -1.62978017
              PC15        PC16        PC17        PC18        PC19        
PC20         PC21
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06047944 -0.192444043
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93431168  0.429668395
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23611648  1.495866675
 [5,] -0.449445186  2.08688147 -1.09672912 -0.34772390  0.38825330  1.7
04403915 -0.616073948
 [6,]  0.267628330  0.24773478  2.34979757 -0.05730764  0.19670773 -1.0
37840949  1.851872593
 [7,]  2.310126960 -0.76615264  1.37894162  0.45920358 -0.16854428  1.0
13511531  1.644114581
 [8,] -1.280909904  1.06302284  0.91788226 -0.38097861 -0.16773209 -1.4
79132666  1.779867641
 [9,] -1.305739991 -0.79558827  1.53791575  0.54039092  0.52926873  2.2
05646237 -0.127968233
[10,]  0.778487579  3.45238501  1.70493131  1.61408675  2.72203269  1.5
55535372 -0.307593036
[11,]  0.046761166  0.11712133  0.33471506  1.59473189  0.25564774 -0.2
74584515  0.119791717
[12,]  0.241008069 -2.11933396  0.05101992 -0.08109695 -3.27821619 -1.7
12421808 -0.431756674
[13,]  1.419088963 -1.11557105  1.58096544  1.62874607 -0.25561135 -1.2
05252297  1.367798610
[14,] -1.086360394 -0.02355151 -1.91910279  0.02404726  0.26320558 -1.5
98323947 -0.978873069
             PC22        PC23        PC24        PC25         PC26        
PC27        PC28
 [1,] -0.04968481 -0.04144832  0.69187267 -2.05173612 -0.036612515  1.2
4431821 -1.11331233
 [2,]  0.68381092 -0.66275921 -0.46322765 -0.18848424  0.664364748  0.1
8740105 -0.90053069
 [3,] -0.17035037  0.82995128  1.60227154 -0.43475737 -0.749490703  0.1
6770141  0.77436817
 [4,]  0.78860576  0.24107738 -0.21739218 -0.50937713 -0.845697203  0.0
7102727  0.68231633
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3494655  1.78725331
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9270283 -0.14997243
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7864473  0.29219840
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6833564  0.82196885
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2723556  1.12119090
[12,]  0.46878481 -1.02625451 -2.49883142 -0.58880343  0.421517175 -0.6
5288383  0.39334687
[13,]  0.95307250 -3.19334836  0.68347574  1.13687818  0.669535938  1.2
7544594  1.13929928
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             PC29         PC30         PC31         PC32        PC33
PC34         PC35
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 [2,]  0.64408412 -0.248411891 -0.783130363  0.517562443 -0.20473041  1
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.285038068  0.286789705
 [5,]  0.49631761 -1.446231585 -0.069771654  0.481111283 -0.37922993  0
.313832336 -0.558307598
 [6,] -1.37353171 -1.069731507  0.408652771  0.556465359  0.51931160  0
.512170377 -0.036068115
 [7,]  0.54198642  0.462862667 -0.506123982  0.434470037  1.42169796 -0
.064227062  1.641044841
 [8,]  0.24665416 -0.979570355  1.070243025  0.768056680  1.49037858 -0
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[10,] -1.15985957  0.551167855  0.392002932 -1.172857607  0.49638298  1
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[11,]  0.32225734  0.545148560 -0.829271776 -0.904050165 -1.70907009  0
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[12,]  0.45005074  0.230051332  0.214898326 -0.398681073 -0.60480854 -1
.121689548 -0.174128174
[13,]  1.02150164  0.110476529  0.048964888  0.137960930  0.62151507  0
.271953151 -0.314051222
[14,]  0.46859871 -0.258236832 -1.024411074 -0.860436165  1.90442024 -0
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              PC36        PC37          PC38        PC39        PC40
PC41         PC42
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 [2,]  0.471328730 -0.38689058  0.9861019235  0.34121627 -0.24355327  0
.32418191  0.058060515
 [3,] -0.832286509 -0.49003272  0.0287362987  0.30091921 -0.43318591  0
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              PC43         PC44          PC45         PC46         PC47
PC48
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 [7,] -0.073841955 -0.361949860  0.3140291499 -0.643412469 -0.092091453
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[14,]  0.061527670  0.299216585  0.2244280189 -0.106254920 -0.085013795
-0.011362337
               PC61         PC62          PC63         PC64         PC6
5          PC66
 [1,] -0.0976097412 -0.038415821  0.1036052807  0.086542638  0.04924569
2  0.012069884
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 [3,] -0.0011893732  0.125654402  0.0043691587 -0.022267836 -0.03400429
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7 -0.068149291
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2 -0.053093406
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3 -0.021102099
 [8,] -0.0725483941  0.002931417 -0.0958812025  0.017078378  0.01561071
7  0.094805826
 [9,]  0.1797572168  0.053436065 -0.1322643318  0.038184640 -0.00372331
6 -0.048810923
[10,]  0.0799108019  0.061551058  0.0443788847  0.007184883  0.01901357
4 -0.002429219
[11,]  0.0627919684  0.065538306 -0.1784828058 -0.175392643 -0.15714625
5 -0.012906586
[12,] -0.0460545119 -0.032550298 -0.0043000690  0.028501613  0.13961832
2 -0.020396060
[13,]  0.1861973609 -0.080199349  0.0184683533  0.114277713 -0.00498668
1 -0.009068307
[14,] -0.0409561264  0.012632425 -0.0647414448 -0.067645150  0.02810779
3  0.019204692
               PC67          PC68          PC69          PC70
 [1,]  3.752306e-02  0.0007455942  3.105150e-02 -2.243431e-15
 [2,]  6.693947e-02  0.0328879130 -3.064610e-02 -3.908766e-15
 [3,] -2.639996e-02  0.0324848739 -2.960271e-02 -3.961675e-15
 [4,] -2.778337e-02  0.0695591873  1.996963e-02 -7.784572e-16
 [5,]  1.883864e-02  0.0396805519  6.137617e-03  4.904497e-15
 [6,]  9.083976e-02 -0.0784608576 -2.863959e-04 -3.327633e-15
 [7,]  6.025887e-02  0.0625031736  6.992507e-03 -4.591379e-15
 [8,] -5.656182e-02 -0.0482697309 -4.047790e-02 -6.544244e-16
 [9,] -7.707666e-02 -0.0294790963  3.053439e-03  1.725616e-15
[10,] -4.286569e-02 -0.0148401016 -3.734512e-03  2.435985e-15
[11,]  9.490957e-03 -0.0194241526 -2.341362e-02  4.082238e-15
[12,] -4.691854e-02 -0.0346761803  3.043965e-02  2.856656e-15
[13,]  2.297625e-02  0.0482753293 -1.422070e-02  6.639654e-16
[14,] -7.836124e-02 -0.0299890199  3.108236e-02 -1.815822e-15
 [ reached getOption("max.print") -- omitted 56 rows ]
```

Interpretation:

The output table represents the principal component scores for each observation in the dataset . Each row corresponds to an observation, and each column corresponds to a principal compo nent (PC1, PC2, PC3, etc.). The values in the table indicate the position of each observation in the new principal component space. PCA reduces the dimensionality of the dataset while retai ning most of the variance. Instead of working with potentially many original features, we now work with a smaller set of principal components. Each PC is a linear combination of the origi nal variables. The first few PCs capture the most variance in the data. For instance, PC1 captu res the most variance, followed by PC2, and so on. The scores indicate how each observation is represented in terms of the PCs. High absolute values in a particular PC suggest that the obs ervation is strongly represented in that component.

- **Performing factor analysis after removing missing values.**

```
# Remove missing values and select numeric columns
> data_processed <- na.omit(data)
> data_processed <- data_processed[, sapply(data_processed, is.numeric)
]
>
# Perform Factor Analysis
> fa <- fa(data_processed, nfactors = 2, rotate = "varimax")
>
# Print the results
> print(fa$loadings)

Loadings:
                                           MR1    MR2
Income                                     0.879 -0.112
X1.Proximity.to.city                       0.494  0.221
X2.Proximity.to.schools                    0.401 -0.222
X3..Proximity.to.transport                       -0.207
X4..Proximity.to.work.place                0.151
X5..Proximity.to.shopping                  0.601  0.358
X1..Gym.Pool.Sports.facility               0.502 -0.157
X2..Parking.space                          0.552
X3.Power.back.up                           0.411  0.111
X4.Water.supply                            0.552 -0.321
X5.Security                                0.521 -0.107
X1..Exterior.look                          0.658  0.502
X2..Unit.size                              0.160 -0.146
X3..Interior.design.and.branded.components 0.738
X4..Layout.plan..Integrated.etc..          0.634
X5..View.from.apartment                    0.754
X1..Price                                  0.343 -0.295
X2..Booking.amount                                0.527
X3..Equated.Monthly.Instalment..EMI.              0.279
X4..Maintenance.charges                   -0.153  0.322
X5..Availability.of.loan                  -0.111  0.676
X1..Builder.reputation                     0.555 -0.292
X2..Appreciation.potential                 0.333  0.209
X3..Profile.of.neighbourhood               0.701 -0.267
X4..Availability.of.domestic.help          0.604  0.146
Time                                              0.311
Size                                       0.857
Budgets                                    0.876
Maintainances                              0.873
EMI.1                                      0.877
ages                                       0.495 -0.137

                 MR1   MR2
SS loadings    9.558 2.067
Proportion Var 0.308 0.067
Cumulative Var 0.308 0.375
```

Interpretation:

The loadings table shows how each observed variable correlates with the two factors (MR1 and MR2). High absolute values (close to 1 or -1) indicate strong correlations, while values close to 0 indicate weak correlations. The study reveals two significant factors influencing buyer behavior. Factor MR1 is strongly correlated with variables like income, size, budgets, maintainances, and EMI.1, indicating financial and housing attributes. Factor MR2 is strongly correlated with Availability.of.loan and Booking.amount, indicating financing options and upfront costs. The factors are interpreted as indicating the buyer's financial capability and housing preferences. Factor MR1 represents economic strength and housing preferences, while Factor MR2 reflects financial flexibility and borrowing capacity. Both factors contribute to the buyer's decision-making process.

Results and Interpretation using Python

- **Performing PCA after converting categorical variables into dummy variables.**

```
encoded_data = pd.get_dummies(data)
pca = PCA(n_components=10)
pca_result = pca.fit_transform(encoded_data)
print(pca_result)
```

```
[[-7.42701380e+03  5.52802843e+03 -2.69791990e+03  2.16237466e+02
   1.94653703e+01 -6.06507127e+00  1.95588881e-02  2.83150915e+00
  -1.68500957e+00  1.29180531e+00]
 [-5.79072281e+04  1.57114306e+04 -1.08213936e+04  3.93253696e+02
   3.79345147e+00  1.33379468e+01  3.35502559e+00  3.75705041e+00
  -1.66503328e+00  7.30791543e-01]
 [-7.72838501e+04  1.11306668e+04  9.36237339e+03 -5.75979399e+01
  -1.02952398e+01  1.58015889e+01 -3.61997592e+00  1.04861177e+00
   2.92160362e-02  4.39298563e+00]
 [ 1.10968269e+05  4.53825095e+03 -6.25976430e+03 -3.32070714e+02
  -7.45796201e+00 -2.28639551e+01 -5.89287504e+00 -1.07394728e+00
  -2.58423608e+00  1.02596477e+00]
 [-7.43029347e+03  5.53190075e+03 -2.70118867e+03 -1.83916811e+02
   6.26322531e+00 -1.39243778e+01  9.56381988e+00  4.06679090e-02
  -3.18998439e-01  2.58229795e-01]
 [-2.52232146e+04 -3.57631258e+03 -2.03064396e+03 -1.31815654e+02
   2.13879271e+00 -3.05335981e-01 -4.30074858e+00  8.21057062e-01
   1.25385706e-01 -1.94971316e-01]
 [ 1.03908580e+05  1.73254868e+04 -1.99185370e+04 -3.94925864e+01
  -1.34471644e+01 -1.71711922e+01  2.48074308e+00  2.56713237e-02
   4.14862908e-01  1.58131697e+00]
 [-7.72846696e+04  1.11316297e+04  9.36156314e+03 -1.57573333e+02
   1.08100074e+00 -3.86282089e+00 -5.64941812e+00  2.63114282e+00
   2.33147621e+00  7.79897161e-01]
 [ 1.03626295e+04  1.46401153e+04 -3.37174016e+03 -2.36013140e+02
  -2.20365616e-02 -9.01235840e+00  9.71124382e+00  3.43449649e+00
   2.91036524e-01 -1.06736418e+00]
 [ 2.82886697e+04 -2.13844315e+04 -1.70687026e+04  1.82048879e+02
```

```
  6.85442509e+00  6.94538901e+00 -2.49608392e+00  1.28362898e+00
  1.46570937e+00  1.88666995e+00]
[-5.44197476e+04  9.39453990e+03 -4.07395627e+03  2.48647320e+02
  7.89367371e+00 -7.48737916e+00  1.64290780e+00 -1.80340704e+00
  6.40468624e-01  9.10325183e-01]
[-3.22828965e+04  9.21091215e+03 -1.56894112e+04  1.60930998e+02
  1.45702266e+01  1.50343563e+00 -3.99148464e+00  1.19663329e+00
  2.64650537e-02 -7.12838759e-01]
[-7.22167666e+04  2.91162715e+02 -3.40749413e+03 -1.99385673e+02
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  8.54510546e-01  1.61427889e+00]
[ 1.04924622e+04 -3.04887663e+04 -1.64014245e+04 -1.66114187e+02
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  2.45782515e+00  1.64587189e+00]
[-5.44197476e+04  9.39453984e+03 -4.07395633e+03  2.48646259e+02
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  6.59150179e-02  5.47878443e-01]
[-7.72846704e+04  1.11316294e+04  9.36156708e+03 -1.57590108e+02
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[-4.73600659e+04 -3.39268512e+03  9.58481029e+03 -4.40923996e+01
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  8.93752511e-01 -1.88655697e+00]
[-4.30161367e+04 -1.26845264e+04 -1.36009514e+03 -7.97274519e+01
  3.93913219e+00  3.63495794e+00 -4.07616813e+00  2.31816890e+00
 -2.05006084e+00 -1.56874484e+00]
[ 3.53483516e+04 -3.41716561e+04 -3.40993478e+03 -1.10704148e+02
 -5.09790156e+00  4.74953972e+00  3.13479903e+00  1.52006182e+00
 -1.09993771e+00  1.62465576e+00]
[-2.08760281e+04 -1.28719992e+04 -1.29722877e+04  2.32270962e+02
 -1.15921285e+01  3.53785468e+00 -1.44575490e+00  1.28891791e+00
 -2.80624708e+00  1.76250901e+00]
[-4.30161367e+04 -1.26845264e+04 -1.36009514e+03 -7.97278664e+01
  3.94069551e+00  3.63762329e+00 -4.04128296e+00  2.58790315e+00
 -1.67538339e+00 -1.91209718e+00]
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[ 3.97659422e+03 -1.65510344e+04  1.59404380e+01 -1.12189129e+02
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 -2.04146045e+00 -8.89959738e-01]
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```

```
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  1.91984572e+00 -4.65880310e-01]
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  1.38648496e+00 -9.43659700e-01]
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  2.62111660e+00  3.12881222e-01]
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[-5.44197466e+04  9.39454043e+03 -4.07395963e+03  2.48652419e+02
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 -1.30194234e-01 -7.45084936e-01]
[ 9.73927065e+04  3.12632312e+04 -3.50118289e+03  1.42697819e+01
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  2.88073995e+00  2.42309361e-02]
[ 1.18031246e+05 -8.25286388e+03  7.40227806e+03 -2.24384342e+02
  1.91209643e+01 -4.90373149e+00 -2.00422570e+00 -7.18262125e-01
 -6.62803768e-02 -1.30992785e-01]
[-1.81635315e+04 -1.63635359e+04  1.16281213e+04 -4.24580886e+02
```

```
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  1.52441381e+00  2.13388232e-01]
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[ 1.18034516e+05 -8.25672169e+03  7.40554067e+03  1.75545140e+02
  9.65241248e+00  4.39164210e+00  9.46553420e-02 -7.66941145e-01
  3.03727264e+00 -3.27504062e-01]
[-4.73600648e+04 -3.39268412e+03  9.58480811e+03 -4.40993881e+01
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  4.47340684e-01 -1.52744678e+00]
[-2.52199472e+04 -3.58017220e+03 -2.02737513e+03  2.68123584e+02
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  1.43731992e+00 -6.14128481e-01]
[ 1.28637112e+05 -2.74529941e+04  2.79067555e+04  1.33615481e+03
 -2.41130200e+01 -5.80486926e+00  2.24419121e+00  7.87741470e-01
  7.20721572e-01  1.85866074e-01]
[-7.72846685e+04  1.11316305e+04  9.36156037e+03 -1.57577391e+02
 -3.52034914e+00  5.02841511e+00 -4.88247319e+00  3.13587962e-01
  1.38341670e+00  1.41398473e+00]
[-7.72846672e+04  1.11316314e+04  9.36155692e+03 -1.57581844e+02
 -9.33319728e+00  1.61819366e+01 -3.65480910e+00 -3.72187031e-01
 -2.03605918e+00  3.44741902e+00]
[ 1.10968269e+05  4.53825138e+03 -6.25976283e+03 -3.32089683e+02
 -6.15286862e+00 -2.35816124e+01  9.15333941e+00 -4.77632181e-01
 -2.62547748e+00  6.26355739e-01]
[-2.95671324e+04  5.71551545e+03  8.91426563e+03 -9.59744376e+01
  1.14112766e+01 -4.08697283e+00  8.76150885e-03 -2.38369534e+00
 -2.17565145e+00 -7.02722098e-01]
[ 1.18034518e+05 -8.25672054e+03  7.40553534e+03  1.75541199e+02
  1.32524715e+00  1.96482278e+01 -4.68506231e+00 -1.15998431e-01
 -1.23954334e+00  6.56423726e-01]
[ 3.53450830e+04 -3.41677974e+04 -3.41320128e+03 -5.10627326e+02
 -1.83153726e+00  6.87783648e+00 -3.25699573e+00 -1.17122186e+00
  2.28493691e+00 -6.33466589e-01]
[-5.00758297e+04  1.02711690e+02 -1.50188659e+04  2.12809608e+02
 -1.41581248e+00 -3.68519530e+00 -2.38559500e+00 -1.77640887e+00
  1.85409407e-01 -1.02346804e+00]
[-2.52199358e+04 -3.58018506e+03 -2.02737019e+03  2.68314092e+02
  2.19601597e+01 -2.54461161e+00  9.72523052e+00  8.20244216e-01
  6.43648432e-03 -1.07148727e+00]
[ 1.10968272e+05  4.53825329e+03 -6.25977249e+03 -3.32082366e+02
 -2.08929971e+01  3.29195565e+00 -3.45337890e+00 -5.19831504e-01
 -2.65293549e+00  3.72610221e-01]
[ 1.18031246e+05 -8.25286388e+03  7.40227811e+03 -2.24385314e+02
  1.91570567e+01 -4.90552178e+00 -1.81033269e+00 -7.43432349e-01
  3.98971700e-01 -9.34767615e-01]
[-1.81635315e+04 -1.63635359e+04  1.16281211e+04 -4.24580243e+02
 -1.47092138e+01  8.18547173e+00  1.17026136e+01  3.46702078e-02
  2.79138239e-01 -5.90947794e-01]
[ 9.73927151e+04  3.12632214e+04 -3.50117965e+03  1.44170449e+01
```

```
 -1.63367483e+00  1.30852826e+01  1.04076822e+00  7.07399303e-01
  5.00430892e-01 -5.90665459e-01]
[-3.67329736e+02 -7.25919473e+03  1.09608404e+04 -7.65055654e+01
 -3.80009919e+00  1.24281113e+01 -4.11977659e+00 -2.39618436e+00
 -1.46401333e-01  8.58143323e-01]
[ 1.47098359e+04  5.34440520e+03 -1.43133785e+04  1.28460368e+02
  1.64667041e+01  1.15610071e+01  2.27696126e+00 -1.91720969e+00
  7.35438803e-01 -1.40989091e+00]
[-4.73600648e+04 -3.39268436e+03  9.58480750e+03 -4.40957136e+01
 -9.70056500e+00 -1.08613387e-01 -4.19140797e+00 -1.35815214e+00
 -2.68036873e+00  1.48998718e-01]
[-2.52232146e+04 -3.57631264e+03 -2.03064394e+03 -1.31815113e+02
  2.19359781e+00 -2.78808059e-01 -4.42438865e+00  1.15214012e+00
 -1.08850398e+00 -2.14777085e+00]
[-7.22167552e+04  2.91149729e+02 -3.40748992e+03 -1.99178394e+02
  1.43140838e+01 -1.15837383e+00  1.23024314e+00 -2.95832751e+00
 -2.32934513e-01  1.35660522e+00]
[ 1.47098291e+04  5.34441637e+03 -1.43133865e+04  1.28304074e+02
 -5.08215663e+00  2.00775414e+01 -1.59800433e+00 -2.12885140e+00
  9.31442712e-01 -7.65293735e-01]
[-5.44197453e+04  9.39454139e+03 -4.07396313e+03  2.48646738e+02
 -2.90268917e+00  1.27519084e+01 -2.60619801e+00 -1.57753183e+00
 -5.58899194e-01 -9.92365087e-01]
[-4.30161467e+04 -1.26845119e+04 -1.36010170e+03 -7.99444392e+01
 -1.90091967e+01  5.16353173e+00  4.30980221e+00  4.23929532e-01
 -6.21987522e-01 -1.24436387e+00]
[ 1.04452424e+05  1.84759654e+04  1.01575969e+04 -2.77836408e+02
  2.88331091e+01  3.26336725e+01  7.23023281e+00  4.42722358e-01
 -8.99035036e-01 -8.12992474e-02]]
```

Interpretation:

The PCA transformation resulted in a matrix where each row corresponds to a data sample and each column corresponds to one of the 10 principal components. The values in this matrix are the coordinates of each sample in the new principal component space. Each value represents the projection of the original data point along a principal component axis. PCA helps in reducing the dimensionality of the data while retaining most of the variance, facilitating easier visualization and analysis.

- Perform Factor Analysis using GPArotation equivalent and Varimax rotation

```
# Performing Factor Analysis using GPArotation equivalent
fa = FactorAnalyzer(rotation='promax', n_factors=5)
fa.fit(sur_int_scaled)

# Get factor loadings
loadings = fa.loadings_
print(f"Factor Loadings:\n{loadings}")
```

```
# Get communalities
communalities = fa.get_communalities()
print(f"Communalities:\n{communalities}")

# Get factor scores
factor_scores = fa.transform(sur_int_scaled)
print(f"Factor Scores:\n{factor_scores}")

# Additional Factor Analysis with Varimax rotation
fa_varimax = FactorAnalyzer(rotation='varimax', n_factors=4)
fa_varimax.fit(sur_int_scaled)

# Get Varimax factor loadings
varimax_loadings = fa_varimax.loadings_
print(f"Varimax Factor Loadings:\n{varimax_loadings}")

# Get Varimax communalities
varimax_communalities = fa_varimax.get_communalities()
print(f"Varimax Communalities:\n{varimax_communalities}")

# Get Varimax factor scores
varimax_factor_scores = fa_varimax.transform(sur_int_scaled)
print(f"Varimax Factor Scores:\n{varimax_factor_scores}")
```

```
Factor Loadings:
[[ 0.45713115 -0.15703226  0.13061431  0.52139636 -0.36036084]
 [ 0.14920559  0.07159923 -0.12304766  0.42708003  0.13165823]
 [-0.01250634 -0.01326014  0.13148086 -0.13322662  0.56875913]
 [-0.06752111 -0.20655468 -0.00230288  0.85963119 -0.05427841]
 [-0.12980614  0.75451035  0.268132    0.15129116 -0.07500403]
 [-0.03429993  0.48312483 -0.11189908  0.19510834  0.146054  ]
 [ 0.07112958  0.49125826 -0.15087578  0.13754612 -0.04639496]
 [-0.16149173  0.41827959  0.02993135  0.44042428 -0.05802163]
 [ 0.2308352   0.31042463  0.07095873  0.11136158  0.69059185]
 [-0.2032866   0.8910738  -0.06997204 -0.15053079  0.27874173]
 [ 0.34157581  0.52003668  0.26881348 -0.17798149 -0.37614504]
 [ 0.33014272 -0.08989056 -0.11451407 -0.13494291 -0.0052787 ]
 [ 0.30543842  0.46323878 -0.04767122  0.12585473 -0.09034353]
 [ 0.43378358  0.17385919 -0.07745727  0.2361559  -0.14471443]
 [ 0.26928465  0.68161341 -0.02763743 -0.13776524 -0.0833587 ]
 [ 0.41089587 -0.10786063  0.01730405  0.11059127  0.42672471]
 [ 0.04285428  0.04103344  0.51635435 -0.07191515 -0.0759222 ]
 [-0.02349027 -0.08044238  0.56333832  0.02401893  0.32381739]
 [-0.07430881 -0.02773161  0.30449517 -0.06987901 -0.02851277]
 [-0.05901541 -0.23537925  0.91632629  0.34868587  0.04319682]
 [ 0.75020372 -0.12850899 -0.09065526 -0.04122603  0.20413555]
 [ 0.36499037  0.03967617  0.27492744 -0.0519493   0.02741634]
```

```
 [ 0.37678689  0.47926694 -0.15897113 -0.14678708  0.22959646]
 [ 0.11570919  0.7673525   0.03420925 -0.35637586 -0.08362717]
 [ 0.03213406  0.09303839  0.381257   -0.05767639  0.0840686 ]
 [ 0.75525549  0.16296433  0.09714898  0.04864463  0.03073481]
 [ 0.86983519  0.08211271  0.08006664  0.02115397  0.05640304]
 [ 0.69081762  0.20049393  0.08742999  0.12288133  0.0977708 ]
 [ 0.75301321  0.12205112 -0.02833379  0.17810344 -0.05247662]]
Communalities:
[0.65240222 0.24226072 0.35885573 0.78914116 0.6865449  0.30650653
 0.29022903 0.39927334 0.64400198 0.94059051 0.63253537 0.14842545
 0.33415671 0.30110672 0.56380283 0.37509317 0.28107802 0.42980744
 0.10470421 1.02198787 0.63090946 0.21382765 0.47119796 0.737386
 0.16543973 0.60971709 0.77339522 0.54972975 0.61720281]
Factor Scores:
[[ 4.32437076e-01 -6.89466623e-01 -1.12044046e+00 -3.92464709e-01
   2.09587373e+00]
 [-4.62026885e-01 -1.69702840e+00 -1.29006973e+00 -8.83250319e-01
   9.55311277e-01]
 [-1.25762078e+00 -8.01466497e-01 -1.50886549e+00 -2.76206663e+00
   1.70790119e+00]
 [ 1.15396827e+00  2.21869815e+00 -2.01753349e+00  1.44518528e+00
   3.96184547e-01]
 [-4.73301920e-01  4.40864670e-01 -1.52892964e-01 -6.26323694e-02
  -9.68125040e-01]
 [-2.82719860e-01 -3.26207288e-01 -3.22542720e-01 -1.54861144e-01
   5.40963629e-01]
 [ 8.23664731e-01  8.82695785e-01  2.50729341e-01  1.02158214e+00
   8.74378730e-01]
 [-1.10987261e+00 -2.36210832e+00 -1.29800335e+00 -1.39464254e+00
   3.66455010e-01]
 [-3.32062779e-01 -1.04074358e+00  2.03746639e-01 -3.44475244e-02
  -1.00409531e-02]
 [ 1.03574729e+00 -3.85383674e-01  4.35421959e-01 -4.33958815e-01
  -9.64747843e-01]
 [-9.70255232e-01 -1.79781697e-01  3.27783566e-01 -8.46002408e-01
  -3.39720979e-01]
 [-5.12514854e-01 -9.89771363e-01 -7.19966130e-01  6.11646680e-01
  -1.21559700e+00]
 [-1.86551198e+00 -2.27030993e-01  6.63309033e-01  8.89311434e-01
   9.28446064e-01]
 [ 1.20626428e-01 -9.58098727e-02  8.26225208e-01  4.59432564e-01
  -1.00748176e-01]
 [-5.82624829e-01 -8.42660826e-01 -5.90010534e-02 -8.85773594e-01
   3.45275275e-01]
 [-2.08522158e+00 -2.14422548e+00  1.67169734e-01 -5.44290960e-01
   1.32902309e-01]
 [-7.84894094e-01 -1.72996513e+00 -1.18929679e-01  3.42340200e-01
```

```
 -5.62768148e-01]
[-9.80312683e-02 -1.16665868e+00 -6.61146332e-01  9.10844161e-01
  1.00363594e+00]
[ 1.26950262e+00  3.26933825e-01 -1.64108819e+00  8.14087059e-01
  4.38552305e-01]
[ 2.44035674e-01  7.21102435e-01 -2.35768100e+00  9.50951627e-02
  6.96432315e-01]
[-9.80312683e-02 -1.16665868e+00 -6.61146332e-01  9.10844161e-01
  1.00363594e+00]
[ 2.30126292e-01 -1.45771050e-01  7.69711485e-01  1.20629093e+00
  2.68811462e-01]
[ 5.01923706e-01 -1.14532283e+00 -7.89356183e-01  9.89035697e-01
  9.22377356e-01]
[-4.34928029e-01  6.34289067e-01  1.14226954e+00  1.39347285e-01
 -6.63400107e-01]
[ 1.46287789e+00  1.76530849e+00 -4.04129066e-02  1.05660120e+00
  7.04174663e-01]
[-4.16808366e-01 -1.80752979e-01 -1.32772885e-01  1.28677046e+00
  3.62489266e-02]
[-1.37960942e+00 -1.69013222e-01  1.10041572e+00  4.48597689e-01
 -6.07631481e-01]
[-2.53570995e-01  5.23267514e-02  8.73919805e-02  6.98966874e-01
  3.69508383e-01]
[-5.85855377e-01 -9.13559807e-01 -3.07076902e-01  9.18142152e-01
  1.02387029e+00]
[ 8.85611913e-01  8.19015916e-01 -6.31675282e-01 -1.59904069e-01
 -7.56677667e-01]
[ 1.78662155e+00  1.09069622e-01 -5.85323218e-01  1.35976674e-01
 -4.29935448e-01]
[-8.89879109e-01 -7.02674040e-01  4.04334728e-02 -7.69795535e-01
 -1.03929175e+00]
[-2.71252190e-01 -6.25554963e-01  1.16861677e+00 -5.83761239e-01
  1.44402540e-01]
[ 3.74684858e-01  1.01349932e+00  6.48354210e-01  1.61562095e-01
  5.46224183e-01]
[-1.21392697e+00 -1.57075312e+00  6.11204853e-01 -1.13782674e+00
  7.03342974e-01]
[ 2.95782943e-01  5.31257543e-01 -8.07831846e-01 -6.18274195e-01
  9.51605015e-01]
[-1.03039903e+00  1.07545238e-01  1.22850922e+00  2.67777031e-01
 -7.41336257e-02]
[ 3.92559273e-01  4.09744440e-01  4.02712196e-01 -1.40386888e-01
 -2.31549299e+00]
[-5.62977423e-02 -1.10776542e-01  5.58067855e-01  5.84960689e-01
  2.09863044e-01]
[-2.10608704e-01 -2.29809125e-01  1.29339442e-01 -1.53126713e+00
 -9.04413057e-01]
```

```
[-7.30949207e-01 -4.71409289e-01 -2.18217124e-01  2.15220651e-01
 -1.04263490e+00]
[ 6.57318181e-01  3.89341936e-01  1.36972285e+00 -1.29127234e+00
  7.34036145e-01]
[ 1.71805336e+00  1.07745118e+00 -1.42326629e+00  5.71451188e-01
 -9.12516061e-01]
[-4.56864337e-01  2.39957206e-01  1.42438289e+00 -7.16701601e-01
  4.92725849e-01]
[-9.67515166e-01 -4.13866543e-01  1.77985437e+00 -2.15432454e+00
 -7.05997095e-01]
[ 1.98906784e+00  8.94825607e-01  8.85210392e-01 -5.00288715e-01
 -7.11238352e-01]
[-8.38421205e-01  4.18909196e-02 -2.27958835e-01 -2.37727181e-01
 -1.96329037e+00]
[ 1.42421317e-01  6.11218609e-02  5.08951564e-01 -8.78652671e-01
 -1.54015411e+00]
[ 1.92050646e+00  1.83168083e+00  1.39482160e+00  1.78405858e+00
  2.17540612e-01]
[-2.04856137e+00 -1.40285895e+00 -8.18635148e-01 -1.13833250e+00
 -1.67689540e+00]
[-1.52909979e+00 -3.46254668e-02 -1.04073305e+00 -1.75296378e+00
  1.50934500e+00]
[ 1.11405939e+00  2.04527811e+00 -5.02933488e-01  1.44787625e+00
  4.85710184e-01]
[-5.01961843e-01  8.59741567e-01  1.78077741e+00  5.45934232e-01
  8.32031397e-01]
[ 1.61516659e+00  1.61677273e+00 -5.61777652e-01  1.05063611e+00
  6.33570631e-01]
[ 8.74670602e-01  5.66301174e-01  5.42399821e-01  8.54859837e-01
 -2.17606114e-01]
[-2.00977607e-01  2.51658232e-02  7.96901461e-02  1.04285156e-02
 -1.63872103e+00]
[ 1.00489805e-01 -3.67897247e-01  1.10915723e+00  1.51670378e-01
 -1.88751444e-01]
[ 1.15396827e+00  2.21869815e+00 -2.01753349e+00  1.44518528e+00
  3.96184547e-01]
[ 1.80528591e+00  6.53226440e-01  1.41829114e+00  5.43848144e-01
  1.25326335e-03]
[-3.74348230e-01  4.01599015e-01  1.38073815e+00  3.43014966e-02
  1.36867987e-01]
[ 9.35558548e-01  4.51232666e-01 -4.34892814e-01 -5.17338128e-01
  1.11891518e+00]
[-1.56555543e-02  8.51049540e-01 -4.98285780e-02 -3.47002096e-01
 -5.29440374e-01]
[ 9.13777292e-01  2.04937208e-01  6.39142566e-01 -3.55782389e-01
 -2.07435085e+00]
[-3.26008384e-01  5.82429447e-01 -1.99566704e+00 -2.16500580e-01
```

```
   1.08654357e+00]
 [-1.93239396e-02 -8.09099976e-01 -3.50392124e-01  6.66140453e-01
   2.34555970e-01]
 [-1.03150065e+00 -1.71296779e-02  1.73023714e+00 -9.07241110e-01
   4.23484271e-01]
 [ 5.39092577e-01  4.31689166e-01  5.52037593e-01 -1.13538401e+00
  -1.47814375e+00]
 [-7.30949207e-01 -4.71409289e-01 -2.18217124e-01  2.15220651e-01
  -1.04263490e+00]
 [-4.20702874e-01 -1.68291388e-01 -6.39110550e-01  1.03526619e+00
  -2.54526831e-01]
 [ 1.36105859e+00  3.18800792e-01  3.66092392e-01 -4.81377141e-01
   1.26048414e+00]]
Varimax Factor Loadings:
[[ 0.33753775  0.71892832 -0.16956858  0.08289052]
 [ 0.22171927  0.40551524  0.25838491 -0.18624163]
 [-0.1209114  -0.22490679  0.50139654  0.07718495]
 [-0.06137541  0.61511256  0.0423535  -0.05585576]
 [ 0.65168374  0.11300809 -0.03225945  0.2513522 ]
 [ 0.42647467  0.14861608  0.22328145 -0.13896273]
 [ 0.52868573  0.18436608  0.07525323 -0.16087285]
 [ 0.35630544  0.30273728  0.01913563  0.01216142]
 [ 0.38240464  0.08615311  0.7516873  -0.04848916]
 [ 0.59416883 -0.19521655  0.27513336 -0.07109695]
 [ 0.78304283  0.08902565 -0.2684961   0.28547653]
 [ 0.12855266  0.03508623  0.07175967 -0.13226527]
 [ 0.69129624  0.28201288  0.07913588 -0.07946822]
 [ 0.5394966   0.42928051  0.05616846 -0.12486113]
 [ 0.82785616  0.04677271  0.05455878 -0.03622455]
 [ 0.15425663  0.20124953  0.5322341  -0.08359564]
 [ 0.10783557 -0.04202842 -0.1403579   0.51892494]
 [-0.10113581 -0.05599313  0.21793623  0.51983825]
 [-0.06806622 -0.09088173 -0.10750336  0.31846585]
 [-0.15004269  0.23878407 -0.0771142   0.87838124]
 [ 0.38843021  0.25417681  0.38648156 -0.17954499]
 [ 0.30941021  0.11771221  0.0870785   0.23419247]
 [ 0.65796281  0.02729788  0.37981054 -0.21219583]
 [ 0.76838875 -0.21268384 -0.02957483  0.05748944]
 [ 0.11812342 -0.05727606  0.03482069  0.36983977]
 [ 0.71321277  0.38287208  0.25716436  0.00867712]
 [ 0.70878539  0.39951411  0.29943785 -0.02133364]
 [ 0.70665881  0.40544176  0.32204271 -0.00791734]
 [ 0.69995152  0.50838568  0.21400196 -0.11326141]]
Varimax Communalities:
[0.666414   0.31505075 0.32255864 0.38704409 0.50168113 0.27313263
 0.34504257 0.2191175  0.72104066 0.47189924 0.77466865 0.04040038
 0.56999944 0.49408353 0.69182238 0.35455785 0.30237833 0.33109169
```

```
 0.12586997 0.85703083 0.39708828 0.17201962 0.62294335 0.63983539
 0.15522763 0.72147228 0.7521064  0.76752389 0.80701311]
Varimax Factor Scores:
[[-5.91900203e-01 -1.13337886e-01  2.06490223e+00 -8.14927454e-01]
 [-1.48995585e+00 -3.67683762e-01  7.81255300e-01 -1.17145386e+00]
 [-5.51814872e-01 -3.37726296e+00  9.52387584e-01 -1.33883708e+00]
 [ 1.89430494e+00  1.34999381e-01  2.68149680e-01 -2.07648044e+00]
 [ 3.31954455e-01 -1.81537821e-01 -1.17934158e+00 -3.62713442e-01]
 [-2.88673919e-01 -4.77204959e-01  3.70031024e-01 -2.11617818e-01]
 [ 5.03973296e-01  6.57472987e-01  1.06609251e+00  4.41395772e-01]
 [-1.92261674e+00 -7.21558792e-01  1.26683683e-01 -1.30038407e+00]
 [-7.12031656e-01  1.09349041e-01 -4.07145625e-02  3.79688614e-01]
 [ 1.58504517e-01  9.86046629e-01 -4.61501751e-01  3.23844092e-01]
 [-3.58593521e-01 -8.78460425e-01 -5.52871382e-01  2.01782044e-01]
 [-1.08283155e+00  1.07633289e+00 -1.33400781e+00 -8.77784874e-01]
 [-1.27240406e+00  8.88134008e-02  5.00872236e-01  8.79515047e-01]
 [-1.48929180e-01  8.03858603e-01  7.25617485e-02  8.51609386e-01]
 [-9.00751079e-01 -5.80302643e-01  1.47854351e-01 -6.91690938e-02]
 [-2.40332317e+00 -2.63512216e-01 -2.26553399e-01  2.84197389e-01]
 [-1.68774390e+00  9.93907231e-01 -5.56983418e-01 -1.30054634e-01]
 [-1.36569209e+00  1.22820158e+00  9.66264990e-01 -3.85451170e-01]
 [ 3.09281018e-01  1.16038597e+00  7.14344026e-01 -1.65174962e+00]
 [ 6.31085624e-01 -7.86643042e-01  3.60368349e-01 -2.32809562e+00]
 [-1.36569209e+00  1.22820158e+00  9.66264990e-01 -3.85451170e-01]
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 [ 5.32005861e-01 -6.22376932e-01 -4.61376983e-01  9.64391833e-01]
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 [ 8.11321271e-01  6.48181858e-01  8.17361414e-02 -6.60418798e-01]
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 [-5.43313500e-01 -9.89571578e-02  2.03983413e-01  1.23752958e+00]
 [ 8.87450306e-01 -4.77199924e-01  6.64758045e-01  7.11020825e-01]
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 [ 4.98068682e-01 -8.12002826e-01  9.32856186e-01 -8.52263654e-01]
 [-3.94879266e-01  1.13673183e-01 -1.86822813e-01  1.26516310e+00]
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 [ 7.72798736e-01 -9.87054832e-01  1.07347785e+00  1.39846739e+00]
 [ 1.23566630e+00  9.30914873e-01 -5.10032346e-01 -1.75728442e+00]
 [ 1.54289463e-01 -7.84540891e-01  6.02577253e-01  1.49182978e+00]
```

```
 [ 3.12802289e-02 -1.93090890e+00 -8.35517583e-01  1.69195318e+00]
 [ 1.53692646e+00  3.79788169e-01 -1.07125601e-01  6.75115351e-01]
 [ 1.31943855e-01 -3.72940478e-01 -2.11245228e+00 -5.84306615e-01]
 [ 6.13893797e-01 -4.94135621e-01 -1.35739407e+00  2.05710348e-01]
 [ 1.79575122e+00  1.42761468e+00  9.32908203e-01  1.51461193e+00]
 [-1.34795043e+00 -7.57040911e-01 -2.36067762e+00 -1.08970433e+00]
 [-4.69798124e-01 -2.65198962e+00  7.74420135e-01 -9.69745957e-01]
 [ 1.64198931e+00  3.90757504e-01  7.01215096e-01 -4.63490553e-01]
 [ 3.47103767e-01 -2.65974126e-01  7.91510246e-01  1.92379755e+00]
 [ 1.38555942e+00  6.07516964e-01  9.43050078e-01 -5.80385724e-01]
 [ 7.45195268e-01  6.78317969e-01  1.70307216e-01  5.83863101e-01]
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 [ 1.89430494e+00  1.34999381e-01  2.68149680e-01 -2.07648044e+00]
 [ 1.00597143e+00  1.16400568e+00  6.97293363e-01  1.46319796e+00]
 [ 2.58818763e-01 -2.35996877e-01  1.88132485e-01  1.48273366e+00]
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 [-1.10427203e-01 -1.39071849e+00  2.17647537e-01  1.90069264e+00]
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 [-4.19997819e-01  7.51946307e-01 -3.56333370e-01 -6.10016262e-01]
 [ 5.16912496e-01 -5.32878675e-02  1.51401859e+00  4.93430876e-01]]
```

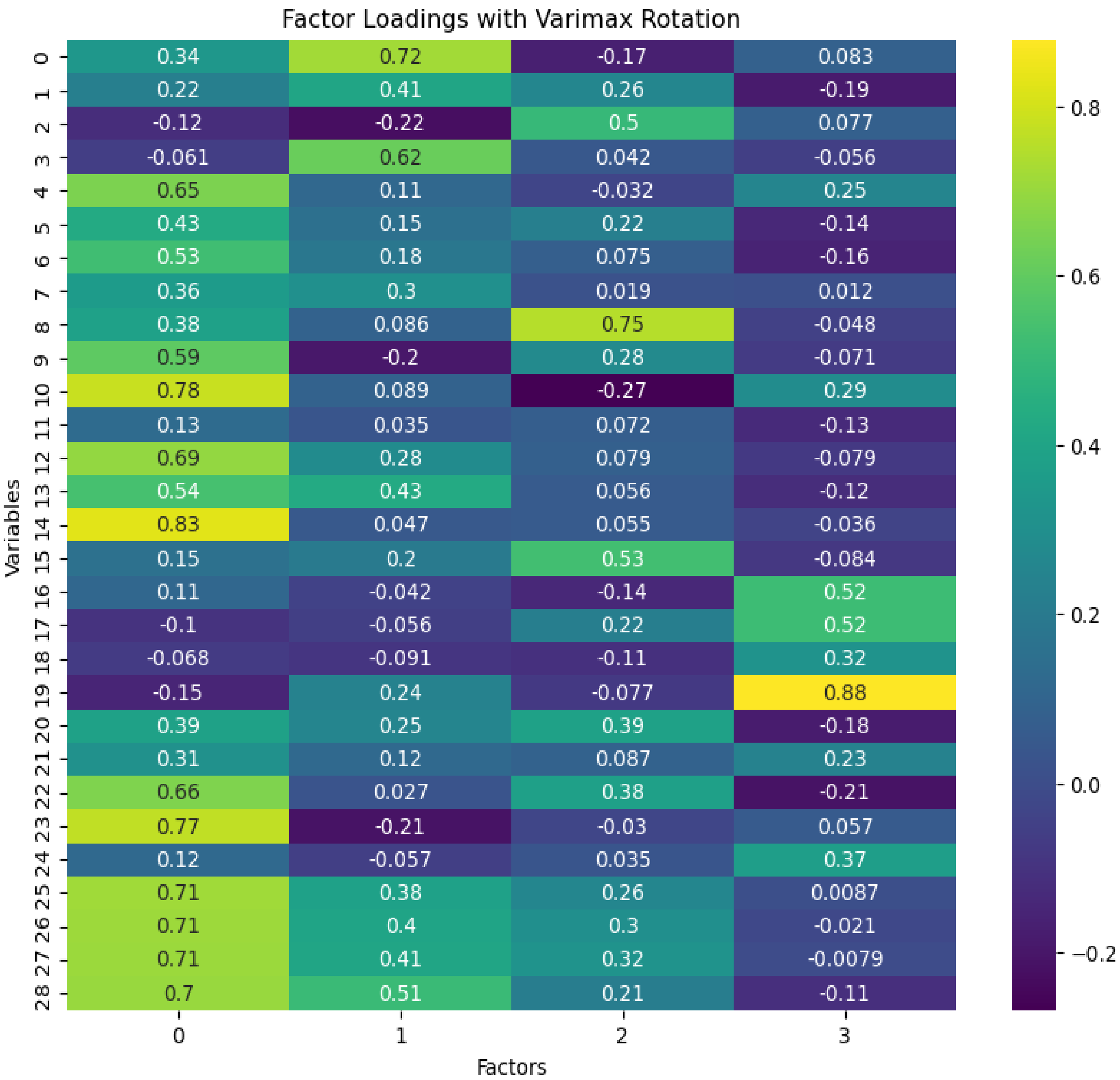
Interpretation:

Factor analysis results can be interpreted using two methods: Promax Rotation and Varimax Rotation. Promax Rotation captures more complex relationships among variables and factors, with higher communalities suggesting stronger shared variance. High positive or negative loadings indicate a strong relationship between variables and factors. Communalities represent the amount of variance in each variable accounted for by the factors, with high communalities indicating most variance is explained by the factors. Factor scores provide a measure of where each observation (sample) stands on each factor, which can be used for further analysis, such as regression or clustering. Varimax Rotation simplifies the structure by maximizing the variance of squared loadings of a factor across variables. High communalities indicate the variance explained by the factors, while low communalities indicate less shared variance among variables. Factor scores indicate the position of each sample on each factor, providing insights into the underlying structure of the data.

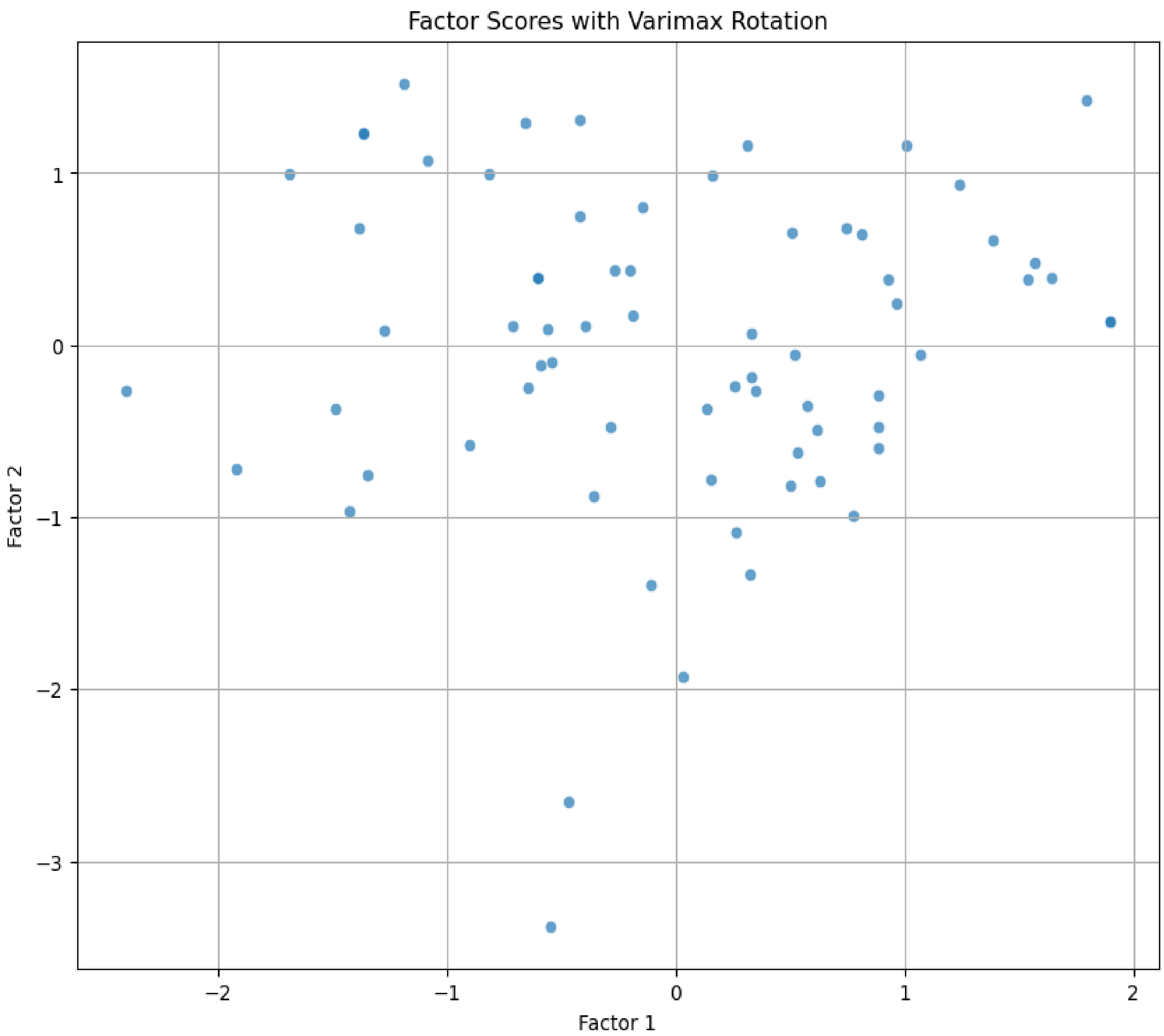
- **Plotting the factor loadings and factor scores**

```
# Plotting the factor loadings
def plot_factor_loadings(loadings, title):
    plt.figure(figsize=(10, 8))
    sns.heatmap(loadings, annot=True, cmap='viridis')
    plt.title(title)
    plt.xlabel('Factors')
    plt.ylabel('Variables')
    plt.show()

plot_factor_loadings(varimax_loadings, 'Factor Loadings with Varimax Rotation')
```



```
# Plotting factor scores
plt.figure(figsize=(10, 8))
sns.scatterplot(x=varimax_factor_scores[:, 0], y=varimax_factor_scores[:, 1], alph
a=0.7)
plt.xlabel('Factor 1')
plt.ylabel('Factor 2')
plt.title('Factor Scores with Varimax Rotation')
plt.grid(True)
plt.show()
```



Interpretation:

The first plot displays a heatmap of factor loadings after varimax rotation, with darker colors indicating stronger associations between variables and factors. The second plot shows the distribution of cases in the space defined by the first two factors after varimax rotation. The axes represent the new dimensions after rotation, and points represent observations. Patterns or clusters in the plot can indicate how cases group together based on their scores on the underlying factors. Similar patterns or groups of points suggest similarity in how cases respond to the underlying factors.

Recommendation

The R script automates the installation and loading of necessary packages for manipulating d ata and doing statistical analysis, creating a seamless workflow for managing a survey dataset . The program reads the data, examines for any absent values, and chooses particular columns for investigation. By utilizing both the GPArotation and FactoMineR packages for Principal Component Analysis (PCA), users can benefit from the flexibility of different methods and vi sualization techniques. Additionally, the factoextra package enhances interpretability by prov iding biplots. The script employs the psych program for factor analysis, utilizing varimax rota tion to provide a distinct structure of factor loadings and scores. To enhance the quality, it is a dvisable to provide comprehensive annotations elucidating each stage, along with a dedicated segment for data cleansing and preparation. In general, the meticulously organized script esta blishes a strong basis for performing Principal Component Analysis (PCA) and Factor Analys is (FA) on survey data.

R Codes

```
#PCA (Principal Component Analysis)

# Load necessary library for dummy variable creation
if(!require(fastDummies)) install.packages("fastDummies", dependencies=TRUE)
library(fastDummies)

# Load the data
data <- read.csv("C:\\Users\\Ferah Shan\\Downloads\\Survey.csv")

# Convert categorical variables to dummy variables
encoded_data <- dummy_cols(data, remove_first_dummy = TRUE, remove_selected_colum
ns = TRUE)

# Remove constant or zero-variance columns
encoded_data <- encoded_data[, apply(encoded_data, 2, function(col) length(unique(col)) > 1
)]

# Perform PCA (prcomp function is part of base stats package)
pca <- prcomp(encoded_data, center = TRUE, scale. = TRUE)

# Print the results
print(pca$x)

#Factor Analysis

# Load necessary library for Factor Analysis
if(!require(psych)) install.packages("psych", dependencies=TRUE)
library(psych)

# Load the data
data <- read.csv("C:\\Users\\Ferah Shan\\Downloads\\Survey.csv")
```

```
# Remove missing values and select numeric columns
data_processed <- na.omit(data)
data_processed <- data_processed[, sapply(data_processed, is.numeric)]

# Perform Factor Analysis
fa <- fa(data_processed, nfactors = 2, rotate = "varimax")

# Print the results
print(fa$loadings)
```

Python Codes

```
import numpy as np
from sklearn.decomposition import PCA
import pandas as pd
from sklearn.impute import SimpleImputer
from sklearn.preprocessing import OneHotEncoder

data = pd.read_csv("C:\\Users\\Ferah Shan\\Downloads\\Survey.csv")

# Principal Component Analysis (PCA)

encoded_data = pd.get_dummies(data)
pca = PCA(n_components=10)
pca_result = pca.fit_transform(encoded_data)
print(pca_result)

# Factor Analysis (FA)

pip install factor_analyzer
import pandas as pd

# Load the dataset
df = pd.read_csv("C:\\Users\\Ferah Shan\\Downloads\\Survey.csv")
```

```
# Check dataset structure
print(df.shape)
print(df.columns)
print(df.head())
print(df.info())

# Remove NA values
print(df.isna().sum())  # Check for NA values
df = df.dropna()  # Drop rows with NA values

# Select columns of interest for factor analysis
sur_int = df.iloc[:, 17:46]

# Standardize the data
scaler = StandardScaler()
sur_int_scaled = scaler.fit_transform(sur_int)

# Performing Factor Analysis using GPArotation equivalent
fa = FactorAnalyzer(rotation='promax', n_factors=5)
fa.fit(sur_int_scaled)

# Get factor loadings
loadings = fa.loadings_
print(f"Factor Loadings:\n{loadings}")

# Get communalities
communalities = fa.get_communalities()
print(f"Communalities:\n{communalities}")

# Get factor scores
factor_scores = fa.transform(sur_int_scaled)
print(f"Factor Scores:\n{factor_scores}")

# Additional Factor Analysis with Varimax rotation
```

```
fa_varimax = FactorAnalyzer(rotation='varimax', n_factors=4)
fa_varimax.fit(sur_int_scaled)

# Get Varimax factor loadings
varimax_loadings = fa_varimax.loadings_
print(f"Varimax Factor Loadings:\n{varimax_loadings}")

# Get Varimax communalities
varimax_communalities = fa_varimax.get_communalities()
print(f"Varimax Communalities:\n{varimax_communalities}")

# Get Varimax factor scores
varimax_factor_scores = fa_varimax.transform(sur_int_scaled)
print(f"Varimax Factor Scores:\n{varimax_factor_scores}")

# Plotting the factor loadings
def plot_factor_loadings(loadings, title):
    plt.figure(figsize=(10, 8))
    sns.heatmap(loadings, annot=True, cmap='viridis')
    plt.title(title)
    plt.xlabel('Factors')
    plt.ylabel('Variables')
    plt.show()

plot_factor_loadings(varimax_loadings, 'Factor Loadings with Varimax Rotation')

# Plotting factor scores
plt.figure(figsize=(10, 8))
sns.scatterplot(x=varimax_factor_scores[:, 0], y=varimax_factor_scores[:, 1], alpha=0.7)
plt.xlabel('Factor 1')
plt.ylabel('Factor 2')
plt.title('Factor Scores with Varimax Rotation')
plt.grid(True)
plt.show()
```

References

1. www.github.com
2. www.geeksforgeeks.com
3. www.datacamp.com