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Defense Perception in the Geopolitical Scope: An exploratory study through unsupervised machine learning

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Abstract

Regarding military development worldwide, the scope of defense has influenced the economic and technological advancement of many nations, whether to defend their sovereignty or lead military power in the global geopolitical scenario. For the study in question, a database from three others is used, composed of 16 variables and 120 countries, exposing defense figures and economic and social indexes respective to each nation. In this scenario, an exploratory analysis is performed, based on statistical modeling and unsupervised machine learning techniques, exposing correlation points between the variables, listing the most influential and influenced in the evaluation scenario. Using clustering techniques through the K-means algorithm and support of the elbow graph, the possible clusters built for the defense scenario are presented, identifying a favorable number of six groups, thus listing the countries with the greatest similarities between their quantitative variables. Finally, the conclusions of the results found are presented, as well as the limitations of the study and proposals for future studies.

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Keywords: Defense Perception; Statistical Modeling; Unsupervised Machine Learning; Clustering.

1. Introduction

In recent decades, the constant changes in the global geopolitical scenario have led to increased competition between the major military powers in the world [1]. The context under exploration focuses on the constant increase in investment in military defense worldwide, with many countries modernizing their armed forces and developing new defense technologies, not only restricting themselves to investment for financial resources but also with the construction of knowledge for technological mastery and strategic exclusivity [2, 3].

Strategic military defense is a crucial aspect of national security, and significant military powers around the globe have invested heavily in advanced defense technologies, including nuclear weapons, missile defense systems, and cybersecurity [4]. In addition, there is a growing concern about the threat of cyber-attacks and the need to protect

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critical infrastructures, such as energy, transport, and communication systems, against possible attacks, considering that the preservation of knowledge is carried out through the use of data [5, 6].

The growing interest in defense technologies is also driving the development of new technologies such as drones, robotics, and artificial intelligence, which are used to improve military forces' intelligence-gathering, surveillance, and strike capability [7–10]. However, at the same time, there is also growing concern about the proliferation of nuclear weapons and the risk of regional and global conflicts [11]. International diplomacy remains an important means of managing tensions between nations and preventing conflict escalation [12].

In this scenario, the strategic military defense landscape in the world is constantly evolving, with the increasing competition between military powers and the need to protect against new threats such as cyber-attacks, maintaining international security and political stability is a constant challenge [13–16]. In this way, understanding the changes and recent geopolitical trends in the world, especially in the scope of the defense and sovereignty of nations, becomes of paramount importance for high-level decision-making, enabling guidance, understanding of the role of the country in a given scenario, and development of strategic capabilities [17, 18].

Understanding strategic military defense scenarios is also critical to international cooperation on security issues such as the fight against terrorism, cybersecurity, and nuclear non-proliferation. International collaboration can help reduce the risk of attacks and increase global security [19–22]. In this context, understanding the influential and influenced variables in the global military sphere becomes vital for force planning and scenario prospecting regarding the role of a given nation in the global geopolitical context [23–26].

Based on an exploratory study of a hypothetical situation, the research in question is dedicated to using unsupervised machine learning techniques to understand scenarios and the relationships between variables in the context of military structures worldwide. For a given evaluation, a database will be composed of 120 nations, unifying military and economic quantitative to understand the possible correlations between their respective variables, as well as the clustering of countries with homogeneous observations and heterogeneous classes among themselves.

The article is divided into four sections. Contextualized already in this section, section 2 is dedicated to exploring the theoretical and methodological foundations that provide the basis for the research to be carried out. Section 3 is dedicated to applying unsupervised machine learning techniques to explore the correlations between variables and constructing possible clusters of countries with similar quantitative characteristics. Finally, section 4 presents the final considerations of the study, along with proposals for future work.

2. Materials and Methods

Unsupervised machine learning models present the implementation of combined statistical techniques for unlabeled data, that is, data that does not have an expected output or a previously defined dependent variable [27]. Commonly, unsupervised modeling is used to find patterns in the given data set, identifying relationships that would not be easily noticeable [28–30].

Notably, this set of statistical models is relevant and essential in the first contact with a given database or problematic situation, helping in the understanding of the variables, their correlations or associations, and respective perceptions of influence on a problem [31–34]. Specifically for unsupervised techniques, it is important to report the impossibility of statistical inference under a given data set, restricting oneself from exploring the data in its current state [35, 36].

In a generalist character, the unsupervised techniques for data of a quantitative nature can be used either for dimensionality reduction between extremely associated variables or for the principle of construction of classes between the grouped observations, the latter being the technique dedicated to the present study [37]. Among the main models, we can mention the Principal Component Factor Analysis (PCA), K-means, and Multiple Correspondence Analysis (MCA), among other techniques [38].

2.1 Clustering

Clustering techniques divide a dataset into groups or clusters according to the similarity between the objects or data points [39]. There are several clustering techniques available, each with its technical characteristics [40]. In this study, the K-means statistical technique will be approached based on the construction of *n* clusters, defined prior to its application by the decision-maker.

The K-means algorithm randomly selects *K* centroids, one for each cluster. It then assigns each data point to the nearest centroid, thus creating the first clusters [41, 42]. After that, the algorithm recalculates the centroids of each cluster, taking the average of the points that belong to that cluster . It then repeats the process of assigning each point to the nearest centroid and recalculating the centroids until they no longer change [43].

In this study, the metric used to measure the distance between the data points and the centroids is the Euclidean distance [44], considering the quantitative data normalized by the z-score [45, 46]. K-means is an iterative algorithm and can be sensitive to the initial choice of centroids. For this reason, it is common to run the algorithm several times with different initial choices of centroids and select the solution that best suits the data. As support in determining the number of clusters, the graphical elbow technique will be used, finding the inflection point in the curve, where the increase in the number of clusters does not lead to a significant reduction in variance [47].

2.2 Methodological Process

The methodological process of evaluation will be established in seven macro stages, the first of which is based on the integration of three different data sets, the first being dedicated to the presentation of economic and social quantitative of the countries [48], the second presenting data related to the military power of each nation [49], and a third base exposing quantitative relationships in numbers of people dedicated to military service for each country [50], both of these referring to the year 2022.

After structuring and unifying the bases, containing a total of 16 variables and 120 countries, descriptive statistical evaluation will be initiated, listing the main quantitative and their respective distributions for each type of variable in exploration. Subsequently, relationships will be analyzed using Pearson's correlation, clarifying the variables of greatest influence on the problematic situation.

Finally, the clustering process will be carried out using the K-means statistical technique and the elbow graph to understand the number of clusters favorable to the evaluation process, along with sensitivity analysis regarding the construction of different class scenarios for different K values.

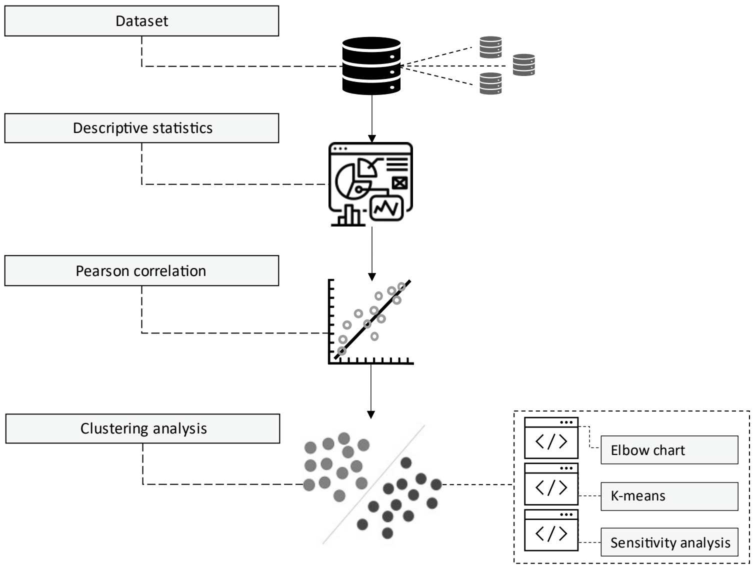

Fig. 1. Methodological process

3. Case Study

As already discussed, the dataset to be analyzed consists of 120 observations, each observation being a respective country, analyzed in the light of a set of 16 variables, all transcribed quantitatively. As computational support, the R language and its RStudio interface were used [1]. For a general understanding of the distributed data, Figure 2 shows [51]the quantitative relationships present in each observed variable.

```
Active military    Reserve military   Paramilitary     Fit-for-Service     Population         Defense Budget     External Debts     Land Resource
Min.   :      0    Min.   :      0    Min.   :      0  Min.   :    79917   Min.   :6.074e+05  Min.   :1.180e+07  Min.   :2.840e+08  Min.   :   20.0
1st Qu.:  15500    1st Qu.:      0    1st Qu.:    950  1st Qu.:  1989370   1st Qu.:5.562e+06  1st Qu.:4.275e+08  1st Qu.:1.146e+10  1st Qu.:  419.8
Median :  39625    Median :   7300    Median :  10680  Median :  4385908   Median :1.720e+07  Median :2.073e+09  Median :4.767e+10  Median : 1058.5
Mean   : 142684    Mean   : 235929    Mean   :  64903  Mean   : 22118278   Mean   :5.856e+07  Mean   :1.654e+10  Mean   :6.813e+11  Mean   : 3720.8
3rd Qu.: 133238    3rd Qu.: 118500    3rd Qu.:  62625  3rd Qu.: 15025599   3rd Qu.:4.399e+07  3rd Qu.:7.064e+09  3rd Qu.:2.478e+11  3rd Qu.: 2934.0
Max.   :2183000    Max.   :7500000    Max.   :1403700  Max.   :619268690   Max.   :1.398e+09  Max.   :7.700e+11  Max.   :2.028e+13  Max.   :51805.0
Naval Resource     Air Resorce        Exportation      Health            Importation          Inflação            Life expectancy   GDP
Min.   :  0.00     Min.   :    0.00   Min.   :  0.109  Min.   : 1.810    Min.   :  0.0659   Min.   : -3.220    Min.   :47.50     Min.   :  327
1st Qu.:  8.00     1st Qu.:   49.75   1st Qu.: 22.775  1st Qu.: 4.817    1st Qu.: 27.3500   1st Qu.:  1.903    1st Qu.:67.72     1st Qu.: 1892
Median : 38.50     Median :  170.50   Median : 34.900  Median : 6.435    Median : 37.7500   Median :  6.225    Median :74.15     Median : 5645
Mean   : 79.88     Mean   :  597.27   Mean   : 39.613  Mean   : 6.820    Mean   : 42.3447   Mean   :  8.390    Mean   :71.89     Mean   :14370
3rd Qu.:107.50     3rd Qu.:  431.25   3rd Qu.: 50.850  3rd Qu.: 8.943    3rd Qu.: 52.8500   3rd Qu.: 11.125    3rd Qu.:77.97     3rd Qu.:19300
Max.   :777.00     Max.   :19620.00   Max.   :200.000  Max.   :17.900    Max.   :174.0000   Max.   :104.000    Max.   :82.80     Max.   :87800
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Fig. 2. Summary of quantitative data

Analyzing the distributions of some main variables, a similarity was identified regarding the generated curve. Figure 3 shows the distributions for the variables Active Military, Defense Budget, GDP, Land, Naval, and Air Resources. It is observed that there is a greater presence of countries in the first columns, representing the minimum quantitative points for each criterion. Observations established at the right ends of each chart are linked to countries of high military power, whether in human, financial, and means resources. A curious fact is that countries with high GDP value do not necessarily have high numbers in defense.

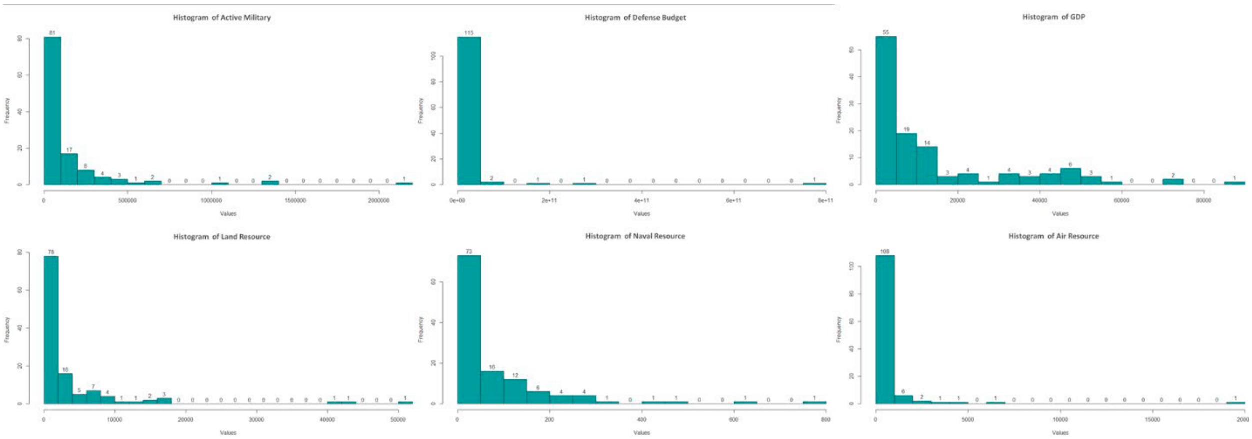

Fig. 3. Distributions for the variables Active military, Defense budget, GDP, Land, naval and air assets

Performing a normalization of the data using the z-score technique, a normalized distribution is obtained in a boxplot graph, as shown in Figure 4. It is understood that the defense variables, going up to the 10th boxplot, indicate a smaller variation between the first and third quartile data, also exposing conditions of outliers above the maximum point of the distribution. The economic and social variables, on the other hand, have a lower concentration between quartiles.

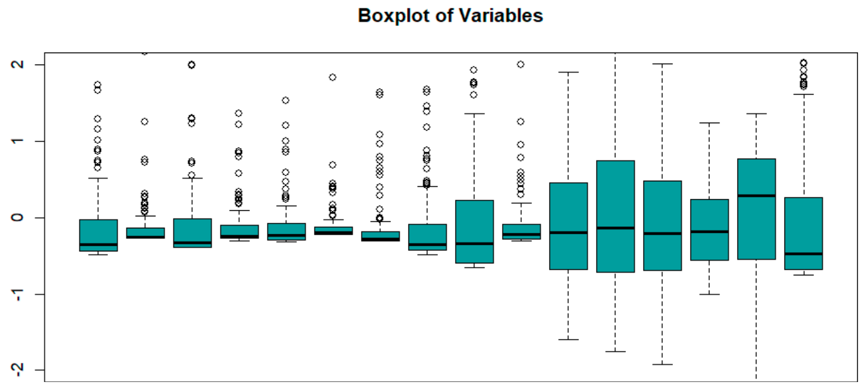

Fig. 4. Variability of normalized quantitative data for the sixteen variables

After the descriptive statistics of the data, the focus of this study is to understand the main correlations between the variables. In this scenario, performing a Pearson correlation between the sixteen variables of this research, as shown in Figure 5, median or close to null indices are observed regarding the degree of correlation, whether positive or negative, between defense and economic and social variables.

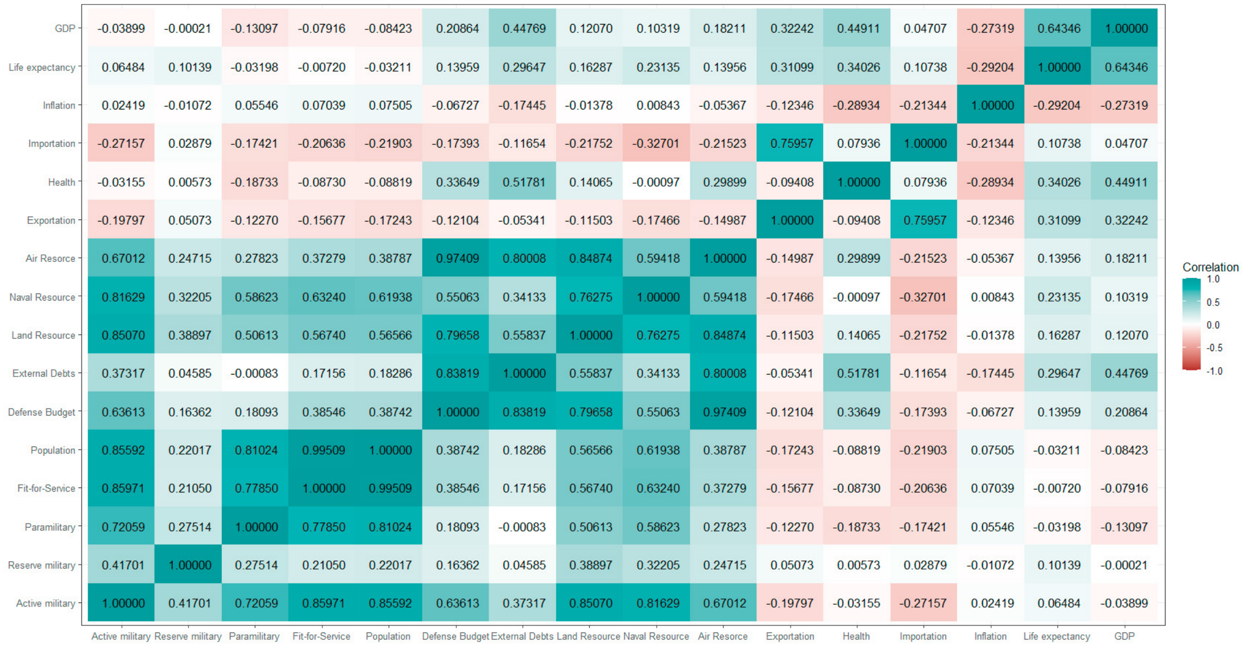

Fig. 5. Pearson's graphical correlation matrix

Analyzing the correlation, it is understood that, based on the datasets under exploration, there is not a great influence of economic and social variables as to the degree of investment or size of a military structure in a nation, for example. If we take as an example the variable Defense budget, it is observed that it only presents a median correlation and, at some points, is high for the variables Active Military, External debt, Land, naval and air resources. Considering the correlation between the defense budget and the country's GDP, we find only a score of 0.208, considered a low observation for correlation purposes. With this assumption observed, the clustering process will be maintained only among the variables being removed, the variables Export, Health, Import, Inflation, Life Expectancy, and GDP.

Considering the application of the K-means clustering technique, the elbow graph is used to understand the favorable number of clusters that can be constructed for the dataset under exploration. Through the graphic technique, it is understood that k=6 is the favorable quantity of clusters, as shown in Figure 6.

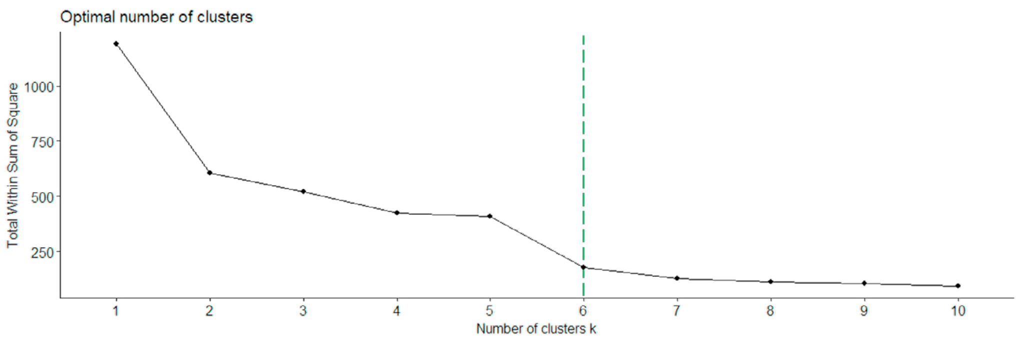

Fig. 6. Elbow chart

Even though the construction of six clusters is indicated, before evaluating k=6, we will observe the clusters built for k=2, k=3, k=4 and k=5, shown in Figure 7.

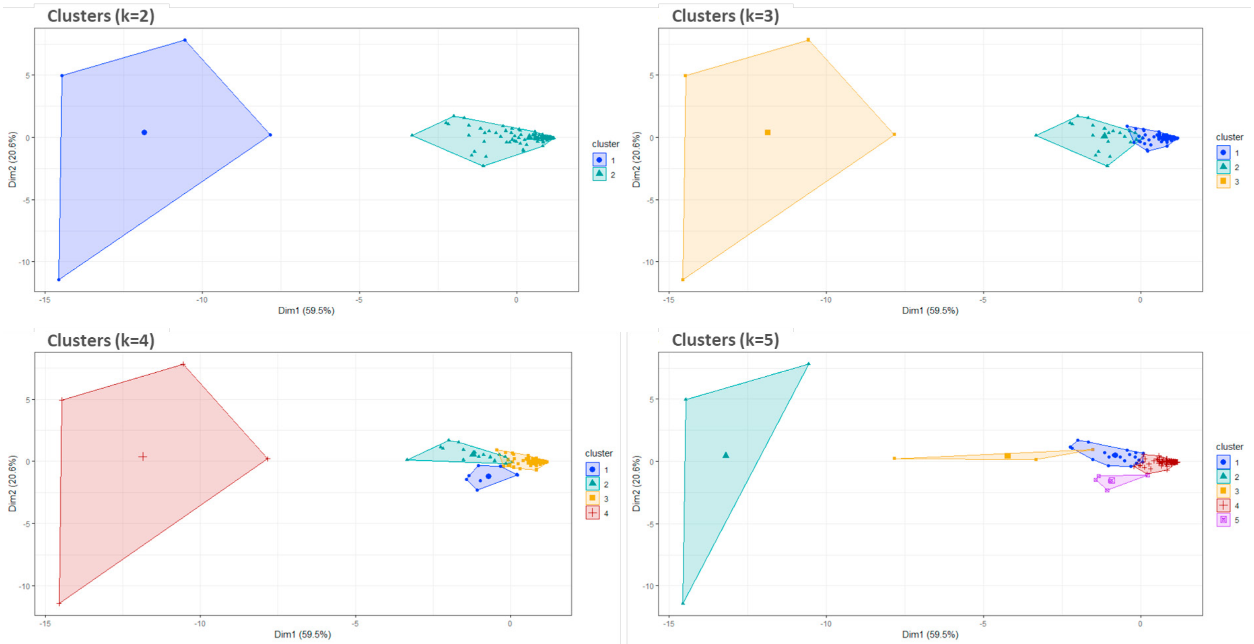

Fig. 7. Clusters for k=2, k=3, k=4, and k=5

Analyzing the clusters, it is observed that already in k=2, a cluster is built with only four countries and another composing the other 116 nations. The 4-country cluster is kept to k=3 and k=4. When analyzed in detail, the observations present in this specific cluster, the countries China, India, Russia, and the United States, are found, both of which present perceptions of high military power around the world. When k=5 is performed, two new main clusters are created, the first containing China, India, and the United States, and a second containing Russia, South Korea, and Vietnam. For k=6, the result is shown in Figure 8.

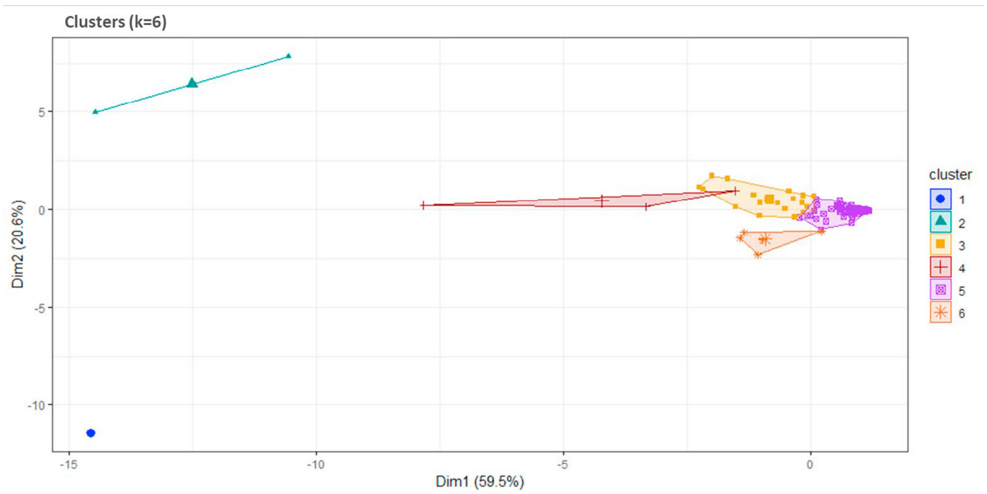

Fig. 8. Clusters for k=6

When the clusters for k=6 are analyzed, the uniqueness of the United States country is identified, presenting itself alone in cluster 1 in blue. Cluster 2, on the other hand, has a composition of two countries, China and India, both of which have high population quantities. A third main cluster, number 4 in red, features a composition of South Korea, Russia, and Vietnam. Finally, a four cluster with few countries is presented, cluster 6, integrating France, Germany, Japan, the Netherlands, and the United Kingdom.

It is noteworthy that the study in question does not seek to obtain predictive analyses but rather to understand correlations between defense variables with economic and social variables, enabling the construction of groups with similar quantitative characteristics between the observations of each grouping performed, not allowing a statistical inference, but rather an exploratory study of the data.

4. Conclusion

The present study aimed to bring an exploratory analysis of the data through the implementation of unsupervised machine learning techniques, seeking the identification of correlations and associations present between the set of variables analyzed from the perspective of defense in the world.

Analyzing a database composed of 16 variables and 120 countries, it was understood that, according to the data explored, there was a low correlation between variables aligned with the perspectives of defenses and the variables based on economic and social indices. Given fact was of paramount importance to understand that not necessarily a country with a large military structure, whether in human resources, finances, or means, there is the same proportion in economic and social issues. The same observation is true for countries with high rates of economic development but not significant investments in defense aspects.

Subsequently, the construction of clusters was explored using the K-means statistical technique, with the support of the use of the elbow graph to clarify the number of clusters favorable to the set of observations. The clusters constructed present perceptions present in the geopolitical scope, where military powers composed the same clusters, with quantitative similarities between the countries of each cluster.

In this scenario, it can be concluded that the study in question was implemented favorably, exposing associations really present in the global geopolitical scenario in terms of perception. It is noteworthy that the study in question was limited to the analysis of data on a public basis referring to quantitative of the year 2022, not strictly exposing the geopolitical reality, but rather an analysis based on quantitative indexes of the dataset and techniques of a statistical nature, not exposing any point of subjectivity of the authors of this research. For future studies, the implementation of other unsupervised techniques, such as factor analysis, will be sought, allowing the reduction of the dimensionality of the variables and the construction of a possible ranking among the countries under the perception of defense around the world.

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