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Food recommendation system based on nutritional needs of human beings and user preferences

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Abstract--Introduction: Nowadays the food types became so diverse and complicated, so human needs+ professional assistance to make his best choices especially after foods became global parameter. Food Recommendation System is a smart system that provides the best suggestions to the beneficiaries to know the best choices to their needs. Moreover, the human activities and lifestyle are affected by another types of dietaries in other foods. There is need for everybody to know what the nutrition is he/she needs. So, this research responding to these needs. The goal of the proposed system is to propose a system that provides recommendations for foods that are rich in nutritional components that people need in their daily lives based on computational model and expert preferences. Objective: The research aims to design and implement a food recommendation system has the ability to coordinate both user preferences and data clustering techniques to produce high accuracy recommendations. Material and methods: The proposed method focuses on merging computational model and user preferences to give the user the best recommended list of food options. Clustering techniques are approaches used in Recommendation system applications to group different foods according to the similarities in nutrition values. The proposed solution uses a combination of Silhouette algorithm and the K-means for weights to obtain the optimum number of clusters early before the clustering process. The weight of each cluster is calculated to use it in determining the rich cluster of food ingredients among other clusters. Results: The results showed an accuracy of 96%. Precision calculation performed using Silhouette algorithm. Conclusions and Recommendations: The system knowledge is limited to the training dataset used. The system performance is upgraded if we use dataset with more food data. The system provides consultation results affected by user preferences.

Keywords---recommendation systems, dietary systems, clustering systems, K-means, Silhouette algorithm, food recommendation.

Introduction

Healthy people usually choose healthy food carefully from a large number of foods that contain vitamins and mineral elements, which correspond to the needs of each person [1]. So, recommendation systems became more and more popular in various areas of our life. Where recommendation systems can provide great benefit when it's necessary to recommend items of food to the people that meet their needs [1]. In this paper, food recommendation relying on machine learning using the clustering approach. The recommendation system known as the smart system that suggests the best suitable target result based on the analysis of user information and the analysis of user interests. Several studies have proven that the recommendation system is the powerful way to solve many problems [1]. Recommendation systems suggest items based on users' past behavior, preferences, and personal data. Given the diversity of data, diversity of information, and wide range of products, recommendation systems are essential to provide recommendations for products and other elements [2]. Recommendation systems help users to find the best option from a huge number of possible options as it meets the requirements of users in a very short time through knowing their initial preferences [3]. Recommendation systems have achieved great performance in various fields such as music, movies, news, books, and products. When user's preferences are unknown to the system, so this kind of problem called the cold start problem [5] which in addition to vague of user preferences could be overcome with the help of clustering methods [6]. The items with the highest similarities grouped together in one group and the items with the highest difference grouped into different groups [7,8]. Clustering operations require a large set of data to achieve high accuracy in the element prediction process and improve the clustering process [9]. To improve the accuracy of the results in this proposed system, we combine a silhouette algorithm that used to determine the best initial number of clusters. the clustering algorithm k-means used to cluster the food types. in this paper, description to the proposed system, food dataset, the proposed algorithm that works with a weights method, and how to determine the clusters that fit to the user's needs are discussed.

Related Works

To investigate the recent updates and trends of using the clustering techniques in the human food recommendation systems, the next is a short review to them. In 2020, A Recommender System for Healthy and Personalized Recipe Recommendations was proposed by Florian Pecune, Lucile Callebert, and Stacy Marsella proposed a recommender system for healthy food recommender system used to change the user food consumption behavior [28].

In 2018, Rui Maia, and Joao C. Ferreira, proposed a food recommendation system, using medical records and mobile devices. Users who pass by food places receive recommendations for types of food based on the available foods that suggested depending on whether these foods are suitable for everyone's health.

Where a method used for recommending recipes based on feature engineering, and matrix factor [14].

In 2017 D.S.Gaikwad et al: built a nutritional recommendation system using data-mining methodology that creates relationships and patterns between foods. The system uses advanced data mining techniques such as machine learning. Through its interface, the system receives the information interactively, which in turn provides the ideal solution for the end user [11].

In 2015, Mehdi Elahi and his et al., Design an interactive food system through a set of interactions amongst short terms and long terms requirements of clients. Long-term preferences taken by asking the user to classify generally desired recipes and the user asked to find preferences for short-term recipes, to determine which ingredients they want in the recipe to be prepared. Based on the similarities between the two types of preferences [12].

In 2013 Sumedh Sawant and Gina Pai presented a dataset from which to extract content-based collaborative features used to find restaurant and customer profiles. Hybrid cascade used to K-nearest neighbor clustering, and a two-part weighted graph projection is used. The system evaluated using Root metrics Mean Squared Error and mean absolute error [13].

In 2010, Maiyaporn Phanich, Phathrajarin Pholkul, and Suphakant Phimoltares: Dietary recommendation suggested using dietary data for diabetics. Alternative nutrients recommend the use of the SOM and K-mean clustering algorithm to analyze foods with similarity and suitability of eight beneficial nutrients important to diabetics [10].

Problem Statement

People need many vitamins, nutrition, and supplements in their daily lives, many people have their choice to buy these supplements, which are manufactured by many food and drug companies. Because most of these nutritional supplements are costly and unavailable in times of crisis and sometimes have side effects, that makes natural sources of food the best solution to avoid these problems. The proposed system greatly contributes helping people to find their nutritional requirements of nutrition by suggesting foods rich with these components through a mixture of algorithms, relying on the components of the materials to achieve the desired goal in a list of foods under study.

The Objectives of Research

Design and implementation of food recommendation system to cope with huge number of food sources, plants and recommends a set of them rich with vitamins and minerals that people need as meals or food supplements making benefits of user preferences.

The Proposed Method

To build a dietary system recommends food rich with vitamin and minerals, there is a need to collect big data about various types of food. And store the data in database designed for this purpose, Figure 1 depicts the proposed system architecture.

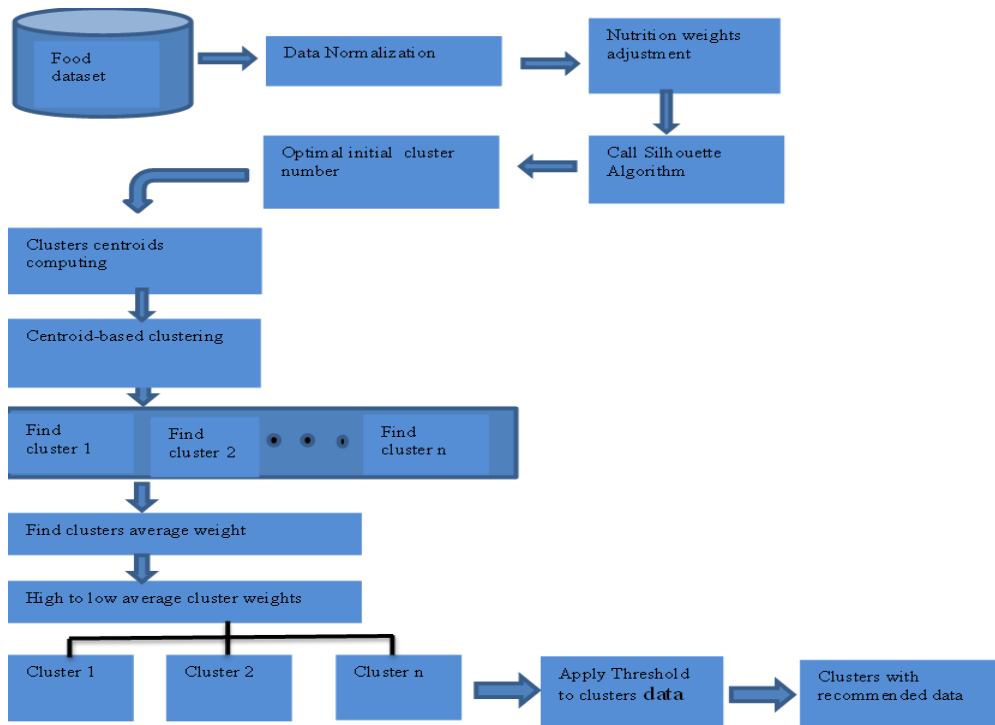


Figure. 1 The proposed system block diagram.

The Food Database

The data base contains a large collection of food (2000 item). Each type of food contains a group of vitamins, iron, and nutritional components . Table 1 represents the structure database for each type of food.

Table 1. Information of food Database

Food ingredients	Measuring unit.
Carbohydrate	G
Manganese	Mg
Pantothenic Acid	Mg
Protein	G
Iron	mg
Magnesium	mg
Sodium	mg
Zinc	mg

Vitamin A	mg
Vitamin B6	mg
Vitamin B12	mg
Vitamin C	mg
Vitamin E	mg
Vitamin K	mcg

Food Nutrition's Weights

Calculating the weights of each food ingredients that contains vitamins, nutrition and other components required to determine their importance to user. The user preferences are adjustable through indicators located in the system user interface, which enables the user to determine the importance value of all the required nutritional components and the other are negligible by setting their indicator to zero value. The weights of each type of food are calculate by equation 1 and the Figure 2 shows how the user determines the importance of each feature.

$$\text{The total weight of food type} = ((\text{nutritional ingredient}(n) \times \text{degree of importance}(n))) \text{ where } n = \text{label of food item in database} \dots\dots (1)$$

Nutritional ingredient degrees of importance are user input as shown in figure 2.

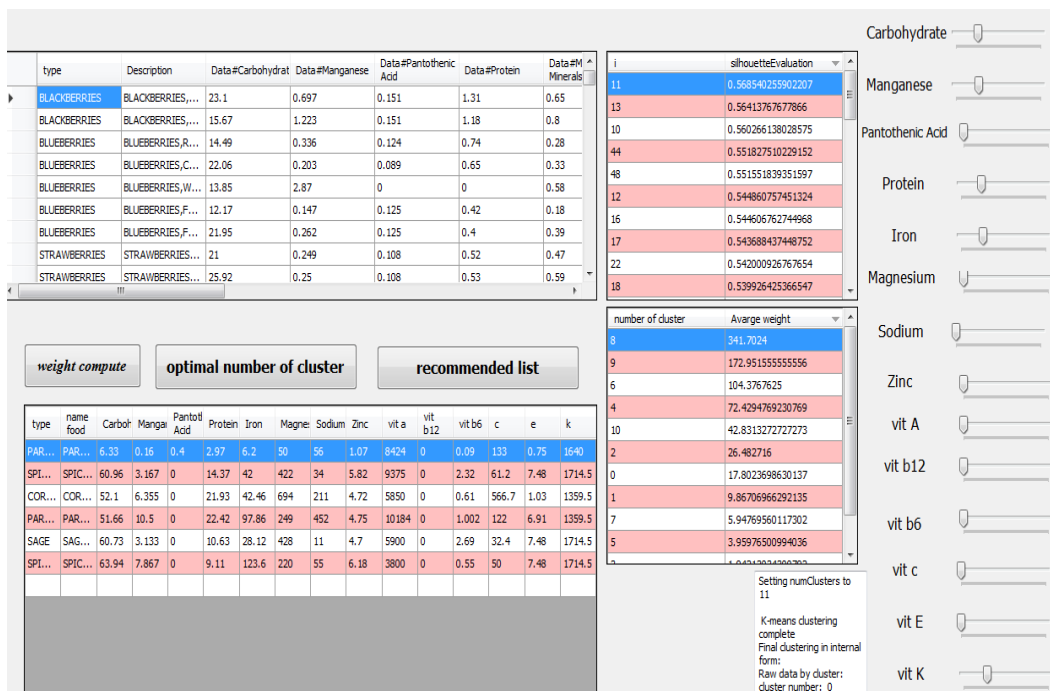


Figure. 2: The proposed system user interface

K-Means Clustering Algorithm

K-means is one of the oldest and popular clustering techniques. It's capable of dealing with large datasets [15,18]. This algorithm finds the approximate solution. Some features of K-means are simplicity, easy to operate, accommodation to data format, medium speed and scalable [16]. The distance is used to measure the difference of the K clusters in the dataset. [17]. The dataset, for example X, contains multiple data points. K is the initial number of clusters which is required and usually specified by the user. By using the Euclidean distance, the similarity extent is calculated between items and centroid of each group [18]. This algorithm is used very widely to determine common elements in form of groups accurately separated and sensitive to modification [19].

Clustering algorithms collect primary information based on the attributes, characteristics, and diversity of that information to perform the clustering process by computing the least distance between the centroid of each cluster and the current elements to put into any cluster [20]. The determination of optimal number of clusters which is decided by the user is key weaknesses of K-means algorithm. The random selection of the centroids affects both the accuracy of the clustering results and the running time [21].

Algorithm 1: K-Means Algorithm [22]

Input: Set the amount of data.

K: Number of cluster (user input).

Output: Data grouped to k-number of clusters.

Start

- 1: determine the number of centroids k.
- 2: Repeat.
- 3: Construct K clusters by allocating each data point to the closest centroid.
- 4: Find each cluster centroid, iteratively, until the data movement stops.

End

Solving the K-Means Weakness

There are many methods used to solve this problem in a smart way by determining the best number of clusters for each type of data, and one of these methods is the silhouette algorithm [23,24].

Silhouette Algorithms

Silhouette is used to measure clustering quality of each data point and how well the clustering quality. Average items of the entire dataset or an individual set is a measure of a clustering quality [25]. It combines decision and cohesion. Consistency is the similarity measure amongst the object and the cluster centroid. The comparison is made by the Silhouette algorithm, the result is in the range -1 to 1. If the Silhouette value is close to 1, it refers to a close match between the current object and the cluster members while the -1 refers to poorly close to the neighbor members. If a dataset is created by a model and it has a

relatively high Silhouette value then the model is appropriate and acceptable [26,27]. The silhouette value is computed as in equation (2)

$$s(i) = \frac{b(i)-a(i)}{\max\{a(i),b(i)\}} \dots\dots\dots(2)$$

$$= \begin{cases} 1 - \frac{a(i)}{b(i)} & \text{when } a(i) < b(i) \\ 0 & \text{when } a(i) = b(i) \\ \frac{b(i)}{a(i)} - 1 & \text{when } a(i) > b(i) \end{cases}$$

$a(i)$ is the sample i intra-cluster dissimilarity.

$b(i)$ is the sample i inter-cluster dissimilarity.

$s(i)$ refers to Silhouette value.

Algorithm 2: Silhouette algorithm for determining K

Input: weight of each food in dataset

Output: number of cluster (K)

Start

Step 1: For $i = 2$ to $i=50$

Step 2: Intra_Mean = (weights of foods / sum of all weights of food in cluster)

Step 3: Inter_Mean (sum of all centroids of clusters) / i

Step 4: if Inter_Mean \geq Intra_Mean then

Max inter_Mean

Else

Max Intra_Mean

End if

Step 5: Silhouette (i) = $\frac{(\text{Inter_Mean} - \text{Intra_Mean})}{\max(\text{Inter_Mean}, \text{Intra_Mean})}$

Step 6: End for

Step 7: optimal number of cluster (k) = max (Silhouette (i))

END

The Modified K-Means Algorithm

Model construction requires a modification to the clustering Algorithm which is applied to cluster foods. The proposed method operates on the average weights, it arranges the clusters from the highest nutritional and vitamin values to the lowest. The work is divided to three stages. In stage 1(data pre-processing) weights are considered. In stage 2, the average weight for each cluster is calculated. In stage 3 threshold value is applied to determine the clusters whose average value higher than the threshold (the winner clusters).

Algorithm 3: The modified K-Means Clustering Algorithm [16]

Inputs:

- Weights of foods calculated using Equation (1),
- Number of clusters (k) computed by algorithm (2),
- Threshold value.

Output: clusters that only contains the recommended foods.

Start

- 1: Read weights.
 - 2: Normalize data.
 - 3: Make the weights the centroids of clusters (k) in random manner.
 - 4: Compute the distance between each weight and all Centroids, the distance is computed using the Euclidean distance.
 - 5: Collect the weights to the nearest centroids.
 - 6: Calculate new centroids for each cluster.
 - 7: Repeat steps 3 through 5 until stability occurs.
 - 8: Calculate the average-weight for each cluster by calculating the total weight of the cluster divided by the number of elements in the cluster.
 - 9: If average-weight \geq the threshold value.
 - 10: sort the clusters from the largest average-weight to the lowest average-weight.
- Step 11: End if
 Step 12: Display suggested clusters to the user
 End

Average Cluster Weights computation

After applying the proposed K-means algorithm the number of clusters (k) is determined and the data is clustered around the k-centroid. To compute the average weight of each cluster, each cluster food members weights are summed and the sums divided by the count of members of each cluster to produce the average weight of the clusters.

Determine the Winning Clusters

The computed threshold is used to determining the best fit clusters which are the clusters with high value of the nutrition subject to query. The threshold value is compared with the average weights of each cluster. If the resulting average value is greater than or equal to the threshold value, the cluster is recommended to the user.

Results and Discussion

C# language, and SQL databases are the SW tools used to develop the proposed system and the SQL-server database is used to store the input dataset and the clustering. The proposed system is a mixture of both modified K-means and Silhouette algorithms to enhance the clustering procedure and boost clustering quality. The input dataset which describes the properties is presented to the clustering procedure, and the centroid seeds (K) is computed by Silhouette algorithm. Modified K-means accepted K as input. The modified procedure calculates and displays the most fit clusters of food. To determine the weights of each food in database, the user have to set what vitamins or nutritional components are needed and what the degree of importance of each component. The table 2 and table 3 shows how to find total weights.

Table 2: The importance of every vitamin and nutritional component

Nutritional ingredient	Importance degree
Carbohydrate	20%

Manganese	20%
Pantothenic Acid	0%
Protein	20%
Iron	20%
Magnesium	0%
Sodium	0%
Zinc	0%
Vitamin A	0%
Vitamin B12	0%
Vitamin B6	0%
Vitamin C	0%
Vitamin E	0%
Vitamin K	20%

The user determining the importance of each nutritional ingredient. The weights of the required component are calculated using Equation 1. Table(3) shows the calculated weights of each type of food.

Table 3: Compute of the total weight

Name of food	Carbohydrate	Manganese	Protein	Iron	vit K	Total weight
Abiyuch,raw	17.6	0.182	1.5	1.61	0	4.1784
Alfalfa seeds,	2.1	0.188	3.99	0.96	30.5	7.5476
Allspice,grou nd	72.12	2.943	6.09	7.06	0	17.6426
Amaranth leaves,raw	4.02	0.885	2.46	2.32	114 0	229.937

The results of clustering accuracy are done and the efficiency test is done. The silhouette algorithm is exploited to fit the nutritional ingredient that belongs to any group and to predict the optimal number of clusters for groups (as shown in Fig. 3 and Table 4). This test clarifies the effect of computing the initial number of clusters which is find by silhouette algorithm on clustering accuracy. Table 4 shows the difference of average value of Silhouette in accordance with number of clusters in the range of 2 to 25.

Table 4: Average value of Silhouette for each number of cluster

Number of Clusters	Average value of Silhouette
K=2	0.542797072860022
K=3	0.527739315820888
K=4	0.530885551759057
K=5	0.531358297674783
K=6	0.547901661204242
K=7	0.560138526509069
K=8	0.557143213508186
K=9	0.542253717356613
K=10	0.560266138028575

K=11	0.578540255902207
K=12	0.544860757451324
K=13	0.56413767677866
K=14	-0.597994921240362
K=15	-0.71501838741997
K=16	0.544606762744968
K=17	0.543688437448752
K=18	0.539926425366547
K=19	0.529759334158076
K=20	0.533250073806159
K=21	-0.728701252981128
K=22	0.542000926767654
K=23	-0.689600234433421
K=24	0.536557162439192

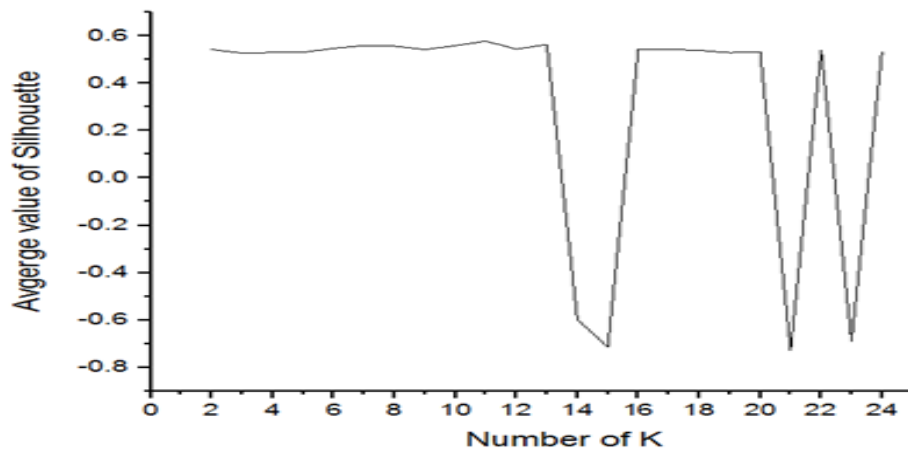


Fig. 3 The relation between computed-K and clustering results (k=11)

Table 5 shows the relation between the number of clusters, number of foods and the cluster average weight.

Table 5: Number of foods and weight of each cluster

Cluster number	Number of foods	Cluster average weight
0	73	17.8023698630137
1	89	9.86706966292135
2	50	26.482716
3	379	1.94213034300792
4	13	72.42948
5	503	3.95976500994036
6	16	104.3768
7	341	5.947696
8	6	341.7024
9	9	172.9516
10	22	42.8313

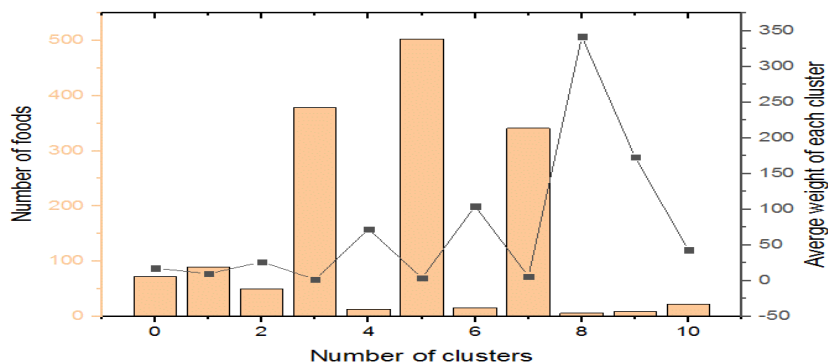


Fig. 4 The clusters average weights

After that, the clusters are arranged so that the clusters that have the highest weights among the other clusters will be the best clusters and their weights are greater than the pre-determined threshold value as in (Table 6).

Table 6: Food clusters recommended to the user

Clusters Number	Average weights of each cluster	Threshold Value	State of clusters
8	341.7024	100	Suggest to user
9	172.9516	100	Suggest to user
6	104.3768	100	Suggest to user
4	72.42948	100	Ignore
10	42.8313	100	Ignore
2	26.482716	100	Ignore
0	17.8023698630137	100	Ignore
1	9.86706966292135	100	Ignore
7	5.947696	100	Ignore
5	3.95976500994036	100	Ignore
3	1.94213034300792	100	Ignore

The results shown in Table 6 show that the clusters 8,9,6 only have average weight higher than the threshold value 100 compared to other clusters. Accordingly, cluster 8 contains the highest recommended foods according to the user's requirements.

Table 7: The recommended foods are in cluster 8

Type of foods	Name of food	Carbohydrate	Manganese	Protein	Iron	vit K
Spices	Spices,basil,dried	60.96	3.167	14.37	42	1714.5
Spices	Spices,thyme,dried	63.94	7.867	9.11	123.6	1714.5
Sage	Sage,ground	60.73	3.133	10.63	28.12	1714.

						5
Parsley	Parsley,dried	51.66	10.5	22.42	97.86	1359.5
Parsley	Parsley,raw	6.33	0.16	2.97	6.2	1640
Coriander leaf	Coriander leaf,dried	52.1	6.355	21.93	42.46	1359.5

Limitations of the Proposed System

There are two weaknesses points:

The system weakness is that it neglected a person's medical history. A person may have common diseases such as diabetes or hypertension etc. The system may recommend food rich in ingredients that may cause harm to the patient. The system recommends in types of food are rich in ingredients may be excess of the actual need of the patient because it ignores age, gender and lifestyle (nutrition, activity). Therefore, we have to enter the person's information to get the right items and the right amounts of each item that fit persons need.

Conclusion and Future Works

This paper deals with a recommendation system for foods suits a specific nutritional ingredient needed by the clients. The system is tested on database with 2000 items of food types, the system results showed that it's more accurate than traditional k-means algorithms. The results tested with one of the methods for evaluating the clustering, using Silhouette algorithm to calculate the inter and intra cluster and gave a value (0.578540255902207) with a small run time (13.52 seconds). Its suggested develop the current system to deal with ingredients and recipes.

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