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A Deep Fuzzy Neural Network System to Group Moroccan Foods: Towards a Personalized Menu for Type 2 Diabetes Patient

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Abstract

Grouping foods is a very hard task because of the noncorrelation between nutrients. The methods based on a single feature led to restrictive groups. In this work, we introduce a grouping strategy that implements deep neural networks and fuzzy C-means. First, we collected the main information on the most consumed foods in Morocco based on 21 nutrients. Second, we use FCM to group similar nutrients. Third, we use the auto-encoder neural network to produce artificial foods by projection of the foods via the nutrients of the same groups. Fourth, we use FCM to decompose the set of foods into an appropriate number of groups. Two data transformations were performed when realizing our system: nutrients grouping and foods projection. In this context, two performance measures are adopted: Mean Square Error (MSE) and Silhouette (S). In this context, our system produces a homogenous group of foods.

Keywords: Deep Neural Network; Fuzzy C-means; Diabete; Diet

Introduction

The main importance of food grouping is to build a flexible diet so that patients maintain their diet over a long period of time to avoid the complex stages of certain chronic diseases such as diabetes. Several research teams have proposed a classification of vegetables by color. Vegetables of identical color have the same nutritional properties. For example, the food guides established by the United States Department of Agriculture (USDA) incorporate the seven fundamental food categories. While the USDA food directories cover all seven basic food categories, the MyPyramid (CNPP 2008) proposes four categories of basic food groups [1-8]. Vegetables provide a high source of vitamins (A, B, C, E), which are vital for health. The body derives numerous vitamins through food. It's advisable to consume a diverse diet, full of a range of foods, in to ensure sufficient vitamins to sustain good health. There are many studies on vitamins and the risk of bladder.

Authors Suppressed Due to Excessive Length cancer (suggested by the World Cancer Research Fund and the American Institute for Cancer Research), and others on vitamin-based regimens for long-term illness, as likewise numerous studies on the contribution of vitamins to good health (vitamin D and bone health) [9,10]. The botanical categorization of plants is guided by physiology, i.e. the features of plant growth, structure, and organization. The utility of botanical categorization to satisfy the requirements of nutritionists is further complicated by the possibility that foods within the same botanical family might or might not include comparable degrees of nutrients. In addition, certain vegetables may be divided into more than one category when multiple parts of the vegetable are found in vegetable. category created when more than one portion of the plant is considered edible. A further difficulty is to categorize fruits and vegetables, in situations plants are consumed individually. Botanical categorization deals with the entire plant and is not limited to the various parts of the plant that are typically eaten. Finally, we point out that most groups established in literature are based on only one feature. Regrettably, these categories are not homogenous enough, as a single attribute is not sufficient to precisely identify foods [8]. In this work, we introduce a grouping strategy that implements deep neural networks and fuzzy C-means. First, we collected the main information on the most consumed foods in Morocco based on 21 nutrients. Second, we use FCM to group similar nutrients. Third, we use the auto-encoder neural network to produce artificial foods by projection of the foods via the nutrients of the same groups. Fourth, we use FCM to decompose the set of foods into an appropriate number of groups. Two data transformations were performed when realizing our system: nutrients grouping and foods projection. In this context, two performance measures are adopted: Mean Square Error (MSE) and Silhouette (S). In this context, our system produces a homogenous group of foods. The rest of this paper is structured as follows: Section 2 presents the main steps of the proposed method. Section 3 gives the experimental results and discussion. Section 4 concerns some conclusions and future directions.

Proposed System

In this section, we give different steps to realize our system, especially data collection, dimension reduction, artificial nutrients building, and foods grouping. At the end of this section, we give the used performance measures to evaluate the components of our system.

Data Collection: first, we collected the main information on the most consumed foods in Morocco based on 21 nutrients (micro and macro nutriments and glycemic load).

Dimension Reduction

In this step, we use FCM to group similar nutrients. In this case, the number of samples is 21 (number of nutrients) and the number of features is 170 (number of foods) [5]. Unlike the hard methods, this method permits the objects to be in different groups, at the same time, using members. Title Suppressed Due to Excessive Length 3 ship functions [6]. To this end, the Fuzzy C-Means try to solve the following optimization problem:

$$(FP): J(\mu, w) = \sum_{i=1}^{N} \sum_{c=1}^{K} \mu_{c=1}^{m} \| z_i - w_c \|^2,$$

where z_i is the ith sample from R^n, $m \in]1,+\infty[$, $\mu_{c,i}$ informs us how much the sample zi is in the group c, and w_c is the center of the cth cluster. Fuzzy C-Means process in iterative optimization of the problem (FP).

Artificial Nutrients Building

In this step, we use the auto-encoder neural network to produce artificial foods by projection of the foods via the nutrients of the same groups [1-3]. The number of auto-encoders equals the number of groups containing more than one nutrient. The auto-encoder is a deep neural network composed of two principal sections: the encoder (box of neurons) and the decoder (box of neurons). The hidden layer gives the coded information, and the last layer must produce the input tests. The loss function E quantifies the sum of the local loosed information when transforming t to artificial tweet : $a_t \| t - \hat{t} \|$. If the encoding operation is realized by a mapping P and D then $a_t = P(W_e * t + b_e)$ and $\hat{t} = D(W_d * t + b_d)$. The global error is given by $E(W_e, W_d) = \sum_{t \in CORPUS} \| P(W_e * t + b_e) - D(W_d * t + b_d) \|$; where $CORPUS$ is the set of the collected tweets.

Foods Grouping

In this step, we use FCM to decompose the set of foods into an appropriate number of groups [4,6,7].

Performance Measure

Two data transformations were performed when realizing our system: nutrients grouping and foods projection. In this context, two performance measures are adopted: Mean Square Error (MSE) and Silhouette (S). Mean Square Error (MSE): if x and $\hat{x} = decoder(encoder(x))$ are the original and the estimated sample, respectively, then the mean square error is defined by:

$$MSE = \| x - decoder(encoder(x)) \|$$

Silhouette: Suppose the data were divided into K groups by any technique, including GMM, fuzzy K-means, K-medoids or K-means.

For the data entry point $i \in G_p$, let

$$A(i) = \frac{1}{|G_p| - 1} \sum_{z \in G_p, i=s} d(i,z)$$ and

$$B(i) = \min_{q \neq p} \frac{1}{|G_q|} \sum_{z \in G_q} d(i,z).$$

If $|G_p| \geq 1$, then the silhouette of i is defined by the equation:

$$s(i) = \frac{B(i) - A(i)}{\max\{A(i), B(i)\}}$$

It should be noted that the larger the silhouette, the more similar the data is to the group to which it was assigned. 4 Authors Suppressed Due to Excessive Length

Experiment Results and Setup

First, we use FCM to group the nutriments into 8 groups (this number is experimentally chosen). (Table 1) gives the obtained groups. We remark that only cluster 3 contains several (13) nutriments, especially vitamins. In addition, the Gly-

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cemic load falls within this group. Second, the foods are projected following each nutrient group using the auto- encoder neural network. Hidden Size=1'MaxEpochs'=3000 'Encoder TransferFunction'='satlin';'DecoderTransferFunction'='purelin';L2WeightRegularization'=0.01;'SparsityRegularizati'SparsityProportion'=0.10.'Sparsity Proportion'=0.10. The mean square error associated with this projection is 81.29 micrograms (Figure 1 & Figure 2 & Figure 3). Third, we use FCM to group the foods into 8 groups (this number is experimentally chosen). (Table 2) gives the food groups silhouette. We remark that all the groups are strongly correlated except the third one. (Table 2) gives the obtained groups. We remark that groups 3 and 6 contain the largest number of foods, which offer a high diversity to the patient's foods. To compare the groups obtained with our system to the ones produced with FCM, directly, we use this later to group the foods. (Figure 4) gives the groups of foods silhouette produced with FCM directly applied to the foods (53.9142). We remark that the silhouette of this latter is less than the one of the groups obtained with our system. Because the clustering methods are incapable of grouping the data and understanding the correlations between features.

Table 1: Nutrients Clustering.

Cluster	Nutrients	Projection error
1	Magnesium (8)	0
2	Phosphorus (7)	0
3	Vitamin (1); Vitamin C (2); Vitamin E (3); Vitamin B6 (4); Vitamin B (5); Iron (Fer) 10; Zinc 11; Protein 13; Carbohydrate 14; Lipids (Tf) 16; Saturated Fatty Acids (SF) 18; Glycemic Load 19	81.29
4	Calories 12	0
5	Potassium 9	0
6	Cholesterol 17	0
7	Sodium 15	0
8	Calcium (Ca) 6	0

Table 2: The groups of foods obtained using FCM.

Shrimp chips; Sauerkraut; Crab; Gnocchi; Cooked lentils, canned; Chocolate bread; Milk bread; Whole wheat bread; Short bread; Whole wheat sandwich bread; Rye and wheat bread; Medium pizza; Octopus; Sardine in oil; Sausage; Ready-made tomato soup;
Peanut; Cooked calf's brain; Shrimp; Raw lamb liver; Cooked lamb liver; Cheese; Virgin olive oil; Avocado oil; Hazelnut oil; Egg yolk; Mussels; Egg; Soft-boiled egg; Roasted pigeon
Apricot; Artichoke; Avocado; Banana; Beetroot; Carrot (peeled, boiled); Celery; Cooked celery; White cabbage; Red cabbage; Cauliflower; Raw kohlrabi; Chives; Zucchini; Cooked zucchini; Shallot; Prickly pear; Fennel; Passion fruit; Pomegranate; Dry white bean (raw); Raw green beans; Carrot juice; Tomato juice (no added sugars); Kiwi; Lentil; Melon; Black mulberry; Cooked turnip; Sweet potato; Dandelion; Leek; Fish (raw whiting); Potato; Red radish; Greengage; Salad; Green salad (without oil); Salsify; Tomato; Vanilla;
Almond; White chocolate; Sesame seed; Sunflower seed; Whole milk powder; Cashew nut; Hazelnut; Pistachio Milk cream; Croissant; Flour; Waffle with or without chocolate; Lobster; Coconut milk; Raw beef tongue; Cooked rabbit meat; Raw whole wheat pasta; Boiled chicken; Dry brown rice; Raw ground beef; Cooked meat
Dried apricot; Garlic; Chestnut; Dried date; Spinach; Frozen fries, microwave-cooked; Pars ley; Chili (harissa); Prune; Raisin
Pineapple; Canned pineapple; Asparagus; Eggplant; Cooked egg white; Cooked broccoli; Broccoli; Raw carrot; Cherry; Dry cider; Lemon; Lime; Clementine; Quince; Cucumber; Whole wheat couscous/semolina; Roasted turkey; Endive; Fig; Strawberry; Raspberry; Plain goat cheese; Guava (canned); Gooseberry; Cooked green beans; Green beans; Pineapple juice; Grapefruit juice; Apple juice; Orange juice; Persimmon; Whole goat milk; Semi-skimmed UHT milk; Pasteurized whole milk; Whole UHT milk; Lettuce; Lychee; Mandarin; Mango; Honey; Blueberry; Raw turnip; Nectarine; Coconut; Onion; Orange; Grapefruit; Papaya; Watermelon; Cooked whole wheat pasta; Peach; Pear; Chickpea; Apple; White grape; Black grape; Grape juice; Rice; Cooked white rice; Tea; Plain whole milk yogurt; Lemon zest
Ketchup; Cow's milk; Green olive; Bell pepper; Tofu

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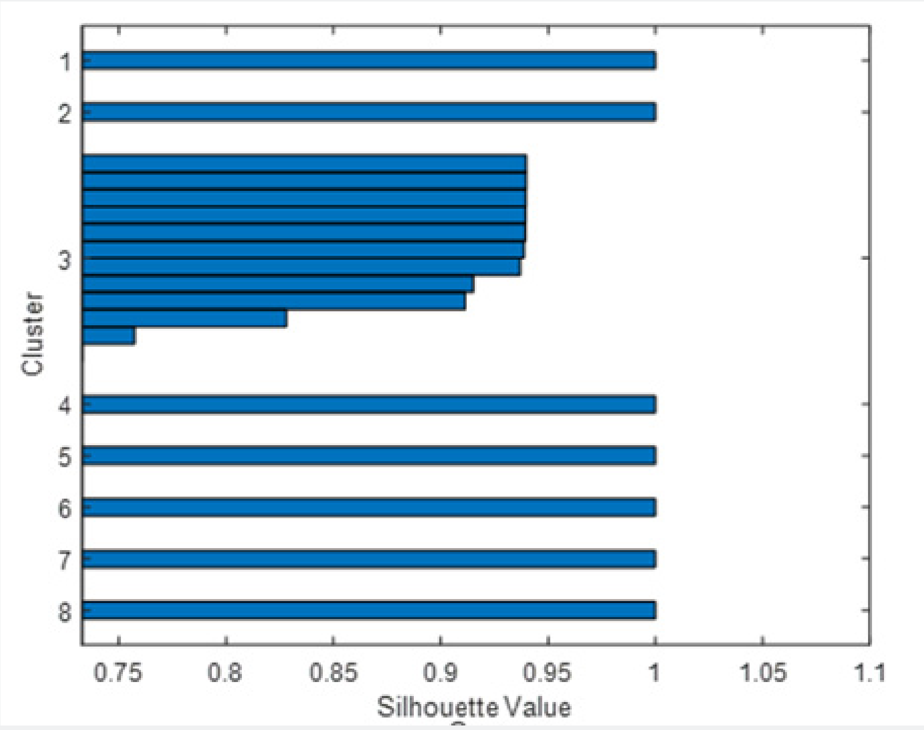

Figure 1: The nutrients groups silhouette (17.7199).

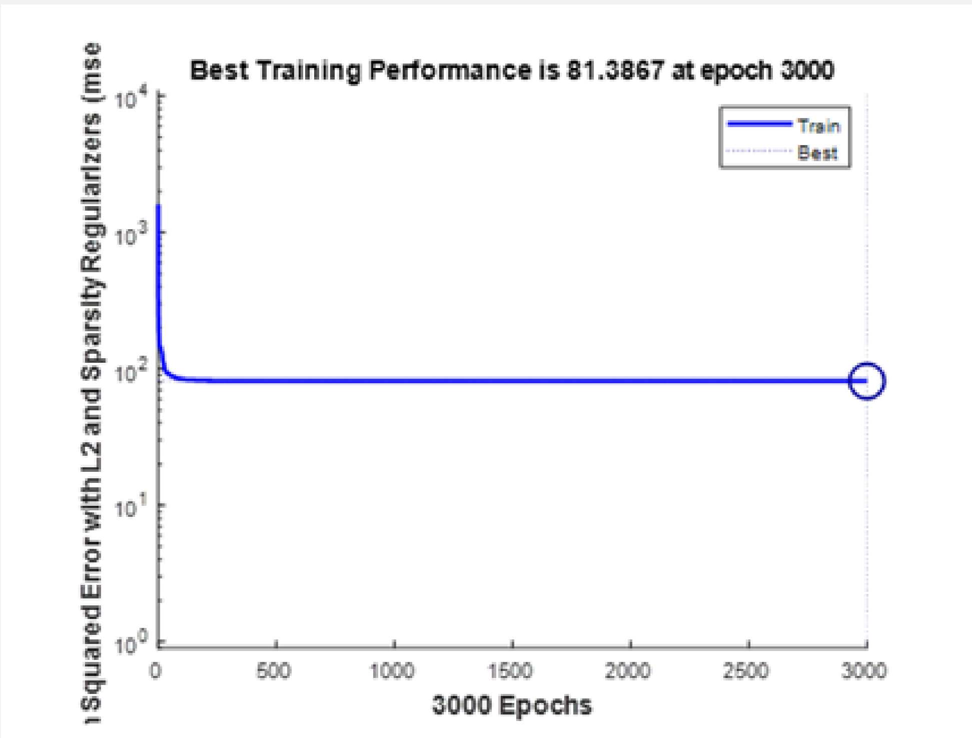

Figure 2: The evolution of the auto-encoder performance with epochs.

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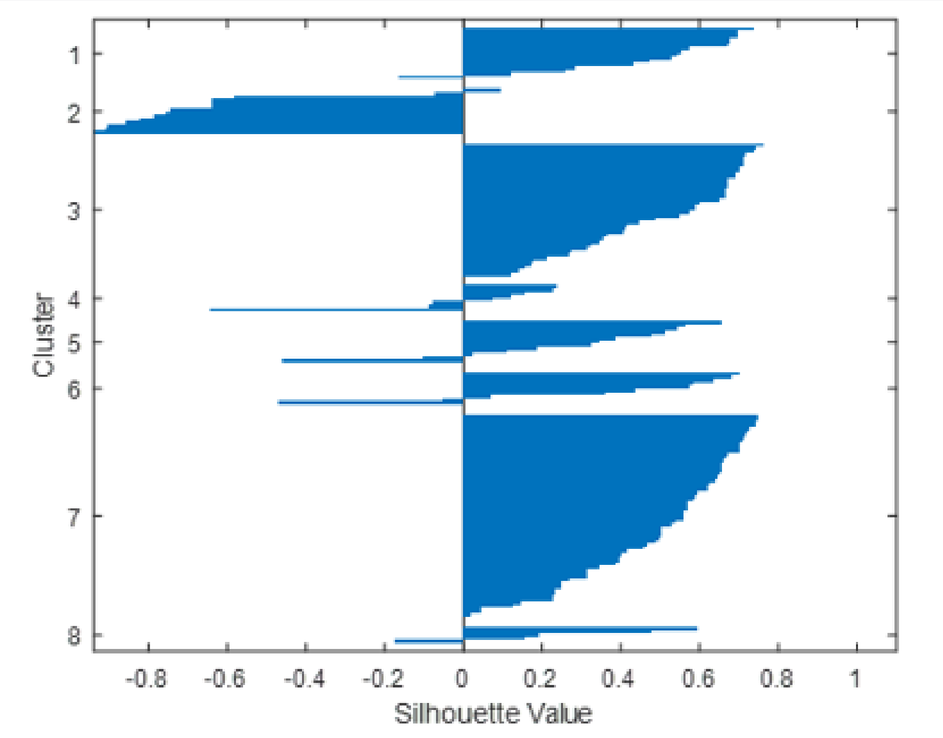

Figure 3: the groups of foods silhouette (59.1838).

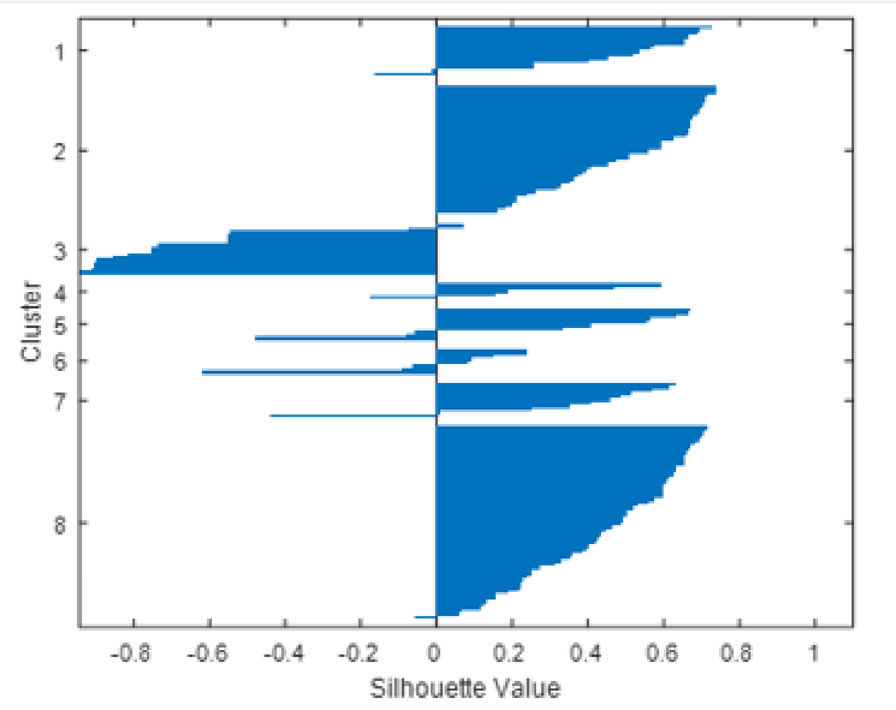

Figure 4: The groups of foods silhouette produced with FCM directly applied to the foods (53.9142).

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Conclusion

In this work, we propose a deep neural network and fuzzy C-means to decompose foods into homogeneous groups. Our method processed into four steps (a) col- lection of the main information on the most consumed foods in Morocco based on 21 nutrients, (b) grouping of the nutriments using FCM, (c) projection of the foods using the auto-encoder neural network, (d) grouping of the foods using fuzzy C-means. The performance of our system was evaluated based on MSE and silhouette. The error of the projection is 81.29 mg, and the quality of the groups is 53.9142mg. As a consequence, our system produces homogenous groups of foods. In future work, we will use our system to build personalized diets for health conditions people, especially diabetic people.

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