DHANALAKSHMI SRINIVASAN
COLLEGE OF ENGINEERING
Coimbatore-641 105
(Approved by AICTE, New Delhi || Affiliated to Anna University, Chennai)

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PROJECT TITLE

AI-POWERED NUTRITION ANALYZER FOR FITNESS ENTHUSIASTS

Submitted By :

1. **ASWIN U (721919104020)**
2. **PRAJODHAY J (721919104043)**
3. **SRAVAN M (721919104056)**
4. **ANSHAD PK (721919104013)**

Guided By :

LITERATURE REVIEW

Food is essential for human life and has been the concern of many healthcare conventions. Nowadays new dietary assessment and nutrition analysis tools enable more opportunities to help people understand their daily eating habits, exploring nutrition patterns and maintain a healthy diet. Nutritional analysis is the process of determining the nutritional content of food. It is a vital part of analytical chemistry that provides information about the chemical composition, processing, quality control and contamination of food. The main aim of the project is to building a model which is used for classifying the fruit depends on the different characteristics like colour, shape, texture etc. Here the user can capture the images of different fruits and then the image will be sent the trained model. The model analyses the image and detect the nutrition based on the fruits like (Sugar, Fibre, Protein, Calories, etc.).

1. McCarthy J., Minsky M., Rochester N., Shannon C.E. A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. [(accessed on 6 November 2020)];1955 Available

The term “artificial intelligence” was first proposed in 1955 by the American computer scientist John McCarthy (1927–2011) in the proposal of a research project, which was carried out the following year at Dartmouth College in Hanover, New Hampshire [1].

2. Nilsson N.J. The Quest for Artificial Intelligence. Cambridge University Press; Cambrige, UK: New York, NY, USA: 2010. [Google Scholar]

Artificial intelligence (AI) as a branch of computer science, the purpose of which is to imitate thought processes, learning abilities and knowledge management, finds more and more applications in experimental and clinical medicine. In recent decades, there has been an expansion of AI applications in medicine and biomedical sciences [2].

3. Ting D.S.W., Pasquale L.R., Peng L., Campbell J.P., Lee A.Y., Raman R., Tan G.S.W., Schmetterer L., Keane P.A., Wong T.Y. Artificial intelligence and deep learning in ophthalmology. *Br. J. Ophthalmol.* 2018;103:167–175. doi: 10.1136/bjophthalmol-2018-313173. [PubMed] [Google Scholar]

The possibilities of artificial intelligence in the field of medical diagnostics, risk prediction and support of therapeutic techniques are growing rapidly. Thanks to the use of AI in ophthalmological , radiological and cardiac diagnostics, measurable clinical benefits have been obtained. AI was used in research on new pharmaceuticals . The development of AI also provides new opportunities for research on nutrients and medical sensing technology [3].

4. Demirci F., Akan P., Kume T., Sisman A.R., Erbayraktar Z., Sevinc S. Artificial neural network approach in laboratory test reporting: Learning algorithms. *Am.J.Clin.Pathol.* 2016;146:227237.[CrossRef] [Google Scholar]

ANNs as a currently widely used modeling technique in the field of AI were inspired by the structure of natural neurons of the human brain. ANNs are mathematical models designed to process and calculate input signals through rows of processing elements, called artificial neurons, connected to each other by artificial synapses. ANNs have been used, among others, to create an experimental decision algorithm model open to improvement, aimed at evaluating the results of biochemical tests confronted with both reference values and clinical data [4].

5. Valletta E., Kučera L., Prokeš L., Amato F., Pivetta T., Hampl A., Havel J., Vaňhara P. Multivariate calibration approach for quantitative determination of cell-line cross contamination by intact cell mass spectrometry and artificial neural networks. *PLoS ONE.* 2016;11:e0147414. doi: 10.1371/journal.pone.0147414. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

This technique was also used in evaluation of cell culture cross-contamination levels based on mass spectrometric fingerprints of intact mammalian cells . The particular usefulness of ANNs has been proven in pharmaceutical analyses . An interesting application of ANNs is the prediction of the relationship between the Mediterranean dietary pattern, clinical characteristics and cognitive functions .

The usefulness of ANNs has been proven in body composition analyses, which have clearly non-linear characteristics [5]. Using ANN modeling, significant benefits can be obtained in clinical dietetics.

6. Dettmar H., Barbour G., Blackwell K.T., Vogl T., Alkon D., Fry F.S., Jr., Totah J., Chambers T. Orange juice classification with a biologically based neural network. *Comput. Chem.* 1996;20:261–266. doi: 10.1016/0097-8485(95)00015-1. Yang M., Cao X., Wu R., Liu B., Ye W., Yue X., Wu J. Comparative proteomic exploration of whey proteins in human and bovine colostrum and mature milk using iTRAQ-coupled LC-MS/MS. *Int. J. Food Sci. Nutr.* 2017;68:671–681. doi: 10.1080/09637486.2017.1279129. [PubMed] [CrossRef] [Google Scholar]Soltani S., Haghaei H., Shayanfar A., Vallipour J., Asadpour Zeynali K., Jouyban A. QSBR study of bitter taste of peptides: Application of GA-PLS in combination with MLR, SVM, and ANN approaches. *Biomed. Res. Int.* 2013;2013:501310.

AI in Food Composition Study: The use of AI techniques in studying the composition of food products and testing their originality dates back to the 1990s. Dettmar et al. used the ANN technique to identify the region of origin of fruit from a set of 16 variables characterizing samples of orange juice . The effectiveness of the applied calculation technique was 92.5%.

Yang et al. used the isobaric tag for a relative and absolute quantification proteomic approach to analyze differentially expressed whey proteins in the human and bovine colostrum and mature milk to understand the different whey proteomes. It may provide useful information for the development of nutrient food for infants and dairy products .

Moreira et al. used topological maps of the Kohonen neural network in the assessment of the procedure for sample preparation of cashew nuts . Shen et al. used laser-induced breakdown spectroscopy (LIBS), least squares support vector machines (LS-SVM) and LASSO models for the detection of six nutritive elements in *Panax notoginseng* (traditional Chinese medicine) samples from eight producing areas . Rasouli et al. applied the whole space genetic algorithm-radial basis function network (wsGA-RBFN) method to determine the content of microminerals of Fe^{2+}, Zn^{2+}, Co^{2+} and Cu^{2+} in various pharmaceutical products and vegetable samples (tomato, lettuce, white and red cabbages) . This group of studies also includes the research of Soltani et al. who used three different

quantitative structure bitter taste relationship (QSBR) models (artificial neural network, multiple linear regression and support vector machine) to predict the bitterness of 229 peptides [6].

7. Huang S.-M., Li H.-J., Liu Y.-C., Kuo C.-H., Shieh C.J. An efficient approach for lipase-catalyzed synthesis of retinyl laurate nutraceutical by combining ultrasound assistance and artificial neural network optimization. *Molecules.* 2017;22:1972. doi: 10.3390/molecules22111972.

Zheng Z.-Y., Guo X.-N., Zhu K.-X., Peng W., Zhou H.-M. Artificial neural network—Genetic algorithm to optimize wheat germ fermentation condition: Application to the production of two anti-tumor benzoquinones. *FoodChem.* 2017;227:264–270.

AI in Research on Production of Nutrients: With regard to research on the optimization of the production of certain nutrients, several studies have been identified in which AI modeling was intentionally applied.

Huang et al. implemented methods of production of a retinol derivative named retinyl laurate by an artificial neural network (ANN) . Zheng et al. studied the optimization of producing 2,6-dimethoxy-ρ-benzoquinone (DMBQ) and methoxy-ρ-benzoquinone (MBQ) as the potential anticancer compounds in fermented wheat germ. They used algorithms of an artificial neural network (ANN) combined with the genetic algorithm (GA) . The ANN model with a Levenberg–Marquardt training algorithm was applied for modeling the complicated non-linear interactions among 16 nutrients in this production process. Kumar et al. used GA-Fuzzy—an evolutionary algorithm comprised of the genetic algorithm (GA) and the fuzzy logic methodology (FLM)—for the optimization of the production of phycobiliproteins (PBPs) from cyanobacteria [7].

8. Vasiloglou M.F., Mougiakakou S., Aubry E., Bokelmann A., Fricker R., Gomes F., Guntermann C., Meyer A.L., Studerus D., Stanga Z. A Comparative study on carbohydrate estimation: GoCARB vs. dietitians. *Nutrients.* 2018;10:741. doi: 10.3390/nu10060741. [PMC free article]

AI in Clinical Nutrients Intake: Among the identified studies on the application of AI in clinical practice, there is a need to distinguish those that aimed to develop systems that monitor, support and modulate the nutrition of chronically ill people. Lu et al. presented a novel system based on AI to accurately estimate nutrient intake, by simply processing RGB depth image pairs captured before and after meal consumption . Oka et al. compared AI-supported nutrition therapy with a mobile application (n = 50) versus human nutrition therapy (n = 50) in a randomized controlled trial . An interesting technological solution in the AI area was used by Vasiloglou et al. in relation to the clinical problem of controlling carbohydrate intake in patients with type 1 diabetes. These authors used GoCARB as a computer vision-based smartphone system in determining plated meals' carbohydrate content. In this study, the estimation of carbohydrate content in 54 plated meals made by GoCARB was compared to the estimation made by six experienced dietitians. It was found that GoCARB estimated the carbohydrate content with the same accuracy as professional nutritionists (p = 0.93) [8].

9. Chin E.L., Simmons G., Bouzid Y.Y., Kan A., Burnett D.J., Tagkopoulos I., Lemay D.G. Nutrient estimation from 24-hour food recalls using machine learning and database mapping: A case study with lactose. *Nutrients.* 2019;11:3045. doi: 10.3390/nu11123045. [PMC free article]

Chin et al. tested the Automated Self-Administered 24-Hour Dietary Assessment Tool (ASA24) on the example of lactose with regard to the Nutrition Data System for Research (NDSR) [9]. ASA24, also known as food diaries, is a web-based tool that enables multiple, automatically coded, self-administered 24-h diet recalls. NDSR is a dietary analysis software application widely used for the collection and coding of 24-h dietary recalls and the analysis of menus. Nine machine learning models have been developed based on the nutrients common to ASA24 and the NCC database. The results obtained in this study suggest that computational methods can successfully estimate an NCC-exclusive nutrient for foods reported in ASA24.

In order to monitor eating behaviors, a rapid automatic bite detection algorithm (RABID) that extracts and processes skeletal features from videos was constructed. Konstantinidis et al. used it to analyze the eating behaviors of n = 59 patients (three types of dishes, 45 meals), the results of which showed an

agreement between algorithmic and human annotations (Cohen's kappa κ = 0.894; F1-score: 0.948) .

Chi et al. proposed a knowledge-based system (KBS) for patients with chronic kidney disease using the Web Ontology Language (OWL) and the Semantic Web Rule Language (SWRL) . In order to evaluate the designed system in recommending appropriate food serving amounts from different food groups, information was collected from *n* = 84 patients. It was found that the OWL-based KBS can achieve accurate problem solving and reasoning questions while maintaining the ability to share and extend the knowledge base.

AI techniques can also be useful in diagnosing mild dehydration. Posada-Quintero et al., using machine learning, investigated the possibility of detecting mild dehydration with autonomic responses to cognitive stress (*n* = 17) . Taking into account the autonomic control indicators based on electrodermal activity (EDA) and pulse rate variability (PRV) in the Stroop test, they obtained 91.2% overall accuracy of mild dehydration detection.

10. Khan A.S., Hoffmann A. Building a case-based diet recommendation system without a knowledge engineer. *Artif. Intell. Med.* 2003;27:155–179. doi: 10.1016/S0933-3657(02)00113-6. Mezgec S., Koroušić Seljak B. NutriNet: A deep learning food and drink image recognition system for dietary assessment. *Nutrients.* 2017;9:657. doi: 10.3390/nu9070657.

In the area of AI applications in the improvement of dietary solutions, two articles describing prototype solutions should be mentioned. Khan and Hoffmann proposed a menu construction using an incremental knowledge acquisition system (MIKAS) . This system asks the expert to provide an explanation for each of their actions, in order to include the explanation in its knowledge base, so MIKAS could in the future automatically perform them.

Fuzzy arithmetic has been used to create "Nutri-Educ"—software for proper balancing of meals, according to the energy needs of the patient. Heuristic search algorithms are used to find a set of actions, acceptable from a nutritional point of view, that will transform the initial meal into a well-balanced one .

Baek et al. applied the hybrid clustering-based food recommendation method that uses chronic disease-based clustering and a nutrition knowledge base . Food products are grouped using the k-means algorithm and food and nutrient data

system. Based on the created clusters and data on food preferences, a knowledge base on diet and nutrition is generated.

Mezgec and Koroušić Seljak introduced a new “NutriNet” tool for food image recognition based on a deep convolutional neural network architecture [10]. It was tested on a collection of 225,953 images (512 × 512 pixels) of 520 different foods and beverages. This tool with an implemented training component is used in practice as a part of a mobile app for the dietary assessment of Parkinson’s disease patients.

11.Panaretos D., Koloverou E., Dimopoulos A.C., Kouli G.-M., Vamvakari M., Tzavelas G., Pitsavos C., Panagiotakos D. A comparison of statistical and machine-learning techniques in evaluating the association between dietary patterns and 10-year cardiometabolic risk (2002–2012): The ATTICA study. *Br.J.Nutr.* 2018;120:32634.doi: 10.1017/S0007114518001150. [Google Scholar]Shiao S.P.K., Grayson J., Lie A., Yu C.H. Predictors of the healthy eating index and glycemic index.

AI in Evaluating Diseases Risks in Relations to Food and Nutrients Patterns: AI techniques also appear to be useful in estimating the risk of health problems based on the analysis of dietary or supplementation patterns. Panaretos et al. used the k-nearest neighbors algorithm and random forests decision tree to assess the 10-year cardiometabolic risk in relation to nutrient and food patterns, n = 3042 (2001–2002) . The authors of the study, using factor analysis, identified factors from foods and nutrients, respectively, explaining 54 and 65% of the total variation in intake. ML techniques were found to be superior compared with linear regression in health score classification.

Berry et al. in n = 1002 twins and unrelated healthy adults groups (PREDICT 1 study) assessed the inter-individual variability of postprandial metabolic responses (triglyceride, glucose, insulin) as potential risk factors for cardiometabolic diseases . On the basis of conducted cohort studies, they developed a machine learning model that predicted both glycemic (r = 0.77) and triglyceride (r = 0.47) responses to food intake.

Naushad et al. developed a breast cancer prediction model based on an artificial neural network (ANN) to investigate how micronutrients (foliate, B12) modulate susceptibility to breast cancer . The developed ANN model explained 94.2% variability in breast cancer prediction.

This group of studies also includes the article by Shiao et al., who examined *n* = 106 participants in multi-ethnic colorectal cancer families in terms of prognostic factors of healthy eating (HEI index) [11]. Machine learning validation procedures were applied, including the ensemble method, generalized regression prediction, elastic net and leave-one-out cross-validation methods.

12. Sun M., Liu Q., Schmidt K., Yang J., Yao N., Fernstrom J.D., Fernstrom M.H., Delany J.P., Sclabassi R.J. Determination of food portion size by image processing. *Annu. Int. Conf. IEEE Eng. Med. Biol. Soc.* 2008;2008:871–874. doi: 10.1109/iembs.2008.4649292.

Hsu M.-H., Huang L.-C., Chen T.M., Chen L.-F., Chao J.C.-J. A web-based decision support system for dietary analysis and recommendations. *Telemed. J.E.Health.* 2011;17:68–75.doi: 10.1089/tmj.2010.0104. [PubMed] [CrossRef] [Google Scholar]

In 2008, Sun et al. proposed an electronic photographic approach and associated image processing algorithms to estimate food portion size . Lu et al., in a recent publication, offered goFOOD^{TM} as a dietary assessment system based on AI. It can estimate the calorie and macronutrient content of a meal, on the sole basis of food images captured by a smartphone .

Yang et al. proposed a new methodological approach in the field of nutritional epidemiology, Ontology for Nutritional Epidemiology (ONE) . It is a resource to automate data integration, browsing and searching. ONE can be used to assess reporting completeness in nutritional epidemiology.

Lo et al. created an objective dietary assessment system based on a distinct neural network . They used a depth image, the whole 3D point cloud map and iterative closest point (ICP) algorithms to improve the dietary behavior management.

Fang et al. estimated food energy based on images and the generative adversarial network (GAN) architecture (*n* = 45) .

Ji et al. assessed the relative validity of an image-based dietary assessment app—Keenoa—and a 3-day food diary in a sample of healthy Canadian adults (*n* = 102) . The authors in this randomized controlled trial showed that Keenoa had better validity at the group level than the individual level and it can be used when focusing on the dietary intake of the general population.

Hsu et al. used the fuzzy decision model to develop a web-based support system that searches food composition databases and calculates dietary intake [12]. This research project was carried out due to the lack of integrated databases for Chinese menus and the need for a decision-making tool for dietitians in Taiwan.

13. Manogaran G., Shakeel P.M., Fouad H., Nam Y., Baskar S., Chilamkurti N., Sundarasekar R. Wearable IoT Smart-Log Patch: An edge computing-based bayesian deep learning network system for multi access physical monitoringsystem. *Sensors* [PubMed] [CrossRef] [Google Scholar]

Ramyaa R., Hosseini O., Krishnan G.P., Krishnan S. Phenotyping women based on dietary macronutrients, physical activity, and body weight using machine learning tools. *Nutrients*. 2019;11:1681. doi: 10.3390/nu11071681. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

AI in Physical Monitoring Systems: AI techniques have found their application not only in monitoring the quality and quantity of nutrients, but also in terms of the level of their expenditure. In the face of the obesity epidemic, these AI applications are very important. Monogaran et al. described the use of a monitoring system as an effective diagnosis tool of physical activities by a wearable smart-log patch with Internet of Things (IoT) sensors . The data were analyzed using edge computing on a Bayesian deep learning network (EC-BDLN). Tragomalu et al. analyzed e-health applications for the management of cardiometabolic risk factors in children and adolescents . Ramyaa et al. tried to phenotype women based on dietary macronutrients and physical activity using machine learning, support vector machine (SVM), neural network and k-nearest neighbors (kNN) algorithms [13].