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Nutrition Estimation and Dietary Assessment in Indian Food through Deep Learning

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Abstract— **Food Nutrition prediction is an interesting area of work before 10 years. There was a active research went on. But after that there was a break of research on this area. Now after corona some active work is going on. As the people are interested to know the intake of their food nutrition. And in this paper proposing the nutrition prediction in the Indian food. In this paper followed the deep learning approach to predict the nutrition in the food. The person who is interested in finding the nutrition intake will capture the image of the food before intake and can get the nutrition values before going to consume. So, it can help the people to get an idea and track of the nutrition they are consuming.**

In this we are using a deep learning approach to find the nutrition in the image. User will capture the food image then that image is sent through CNN model. then by the CNN model will find what food item is captured. And before capturing the image will ask user information also like name, age, height and weight. So will calculate the BMI and the nutrition required for the person. And will store the nutrition content user is consuming in every meal. So, at end will show the BMI of the user, and present nutrition user is consuming from the meal and total nutrition user has to consume in a day. Our model for food classification achieved an accuracy of 91.87%

Keywords— Deep Learning, Convolutional Neural Networks, TensorFlow, Keras, Dietary management, BMI (Body Mass Index), Transfer Learning, Data collection, Machine Learning, Pretrained models

I. INTRODUCTION

Food is basic and need for everyone and it plays the crucial impact on the living quality of the people health. Last 10 years people food habits got changed very rapidly because of globalization we are having access to all type of food varieties. So, food habits changed a lot. but not maintaining the balancing between intake nutrition and their consumption. And the working habits got changed a lot. Need to make a close watch on the intake food nutrition for healthy lifestyle. These days having access to many varieties of food, having so many new varieties of foods and eating all the items. But the amount of food intake and the amount energy spending is not balancing so leading to unhealthy lifestyle and diabetics. So having a close watch on the consuming nutrition and spending nutrition amount is very important thing to consider. And these days most of the people are actively looking into their diet. More and more people are actively interestingly looking into their nutrition intake. Especially after corona pandemic. People are more conscious into their food habits. Looking into the nutrition facts of the food they are consuming. And became more interested into the amount of food they are consuming and amount of energy they are spending.

II. RELATED WORK

Finding nutrition content in the food had good research and it is still going on. as many ways are joining in finding nutrition content. from machine learning approach to deep learning approach.

A. Dietary Assessement via Deep Model

Food nutrition prediction based on deep learning approach is an active, interesting approach. LANDU JIANG *et al.* [1] done the nutrition prediction and dietary assessment work in predicting the nutrition on FOOD101, UEC-FOOD100 and UEC-FOOD256 data. They used the deep learning approach, initially they applied Region Proposal network (RPN) which is derived from faster R-CNN. Then they applied the CNN model on the selected Region of Interest which got from Region Proposal Network (RPN). Then the nutrition in the food will be predicted. And, they have generated a new FOOD20-with-bbx dataset from the FOOD101 dataset which is got after applying the RPN on the FOOD101 dataset. But the limitation of this paper is in this the nutrition prediction is done per serve. So, the user cannot get the clear or complete idea of the nutrition intake, this approach just provided the nutrition information per serve. All people will not eat the same amount of food, so this paper is not provided the information of nutrition present in the 1 spoon of food to large amount of food captured, just provided the information of nutrition in 400grams/1 serve of food.

B. Measuring Calorie and Nutrition From Food Image

Food nutrition prediction based on Machine learning approach followed by Parisa Pouladzadeh *et al.* [2]. They proposed the nutrition prediction approach on some fruits, Meat, cheese and vegetables like total 15 classes used. In this approach various feature like shape, size, texture and color are extracted and these features are sent to the Support Vector

Machine (SVM). This model will identify the food item. With segmentation technique they have differentiated different food items in the plate and then in this paper for predicting the mass of the food one interesting approach is used that is the user when capturing the image of the food has to take the picture from top view and side view then from this both views author predicted the volume of the food and with the density table calculated the mass and then estimating the nutrition in the food based on the predicted mass. For predicting the area this paper used the approach like they made equal grids of squares on the segmented image. Each square will have the same number of pixels, so each grid is of same area. Then the area of the food available is the sum of grid areas. Based on the fineness of the grids the accuracy and fastness of prediction will depends.

C. Region-Wise Deep Learning approach for Food Ingredient Recognition

There is a work done by Chen *et al.* [3] on the data Vireo Food-251. This dataset is of 251 Chinese food classes and along with food items it also holds 406 ingredients information. This author used DCNN (Deep convolutional Neural Networks) for food recognition. This approach follows 2 methods, first method is multi-task model for recognizing food and ingredients. Second method is single task model for recognizing the label of ingredients at local image regions.

D. A Food Recognition System Based on an Optimized Bag-of-Features Model

The food recognition work done by Anthimopoulos *et al.* [4]. In this paper author developed a model to estimate the meal's carbohydrates content bases on BoF (bag-of-features model). And the dataset of 4868 images with 11 classes are collected from web sources by the author. In this process author first extracted the key points using SIFT detector. After getting key points produced the feature vectors. And then made five color histograms. Then to find the most repetitive patch applied k-means clustering built a visual dictionary of 10000 words. And to classify the image author applied linear support vector machine classifier (SVM). The Recognition of images given an accuracy of 78%.

In this research field, not only just intake nutrition estimation work, but there is also work done some authors in finding the Left-over nutrition. Sari *et al. [5]* done the work in finding the Left-over food nutrition estimation by image segmentation techniques.

E. Food Classification and Ingredients estimation

Sukvichai *et al.* [13] done nutrition estimation work on Thai fast-food dishes, the data on this paper worked consist of 6 classes. Author used pretrained model, which is MobileNet for food classification, and for detecting the ingredients in the classified food YOLO (you only look once) network is used. YOLO network not only detects the ingredients present in the image; it also locates the ingredients. after YOLO detects the location of the ingredient that position will be cropped, and that cropped image will be gone through some image processing techniques to estimate the area. Then based on the area will estimate the nutrition. And author transferred the model on to Raspberry pi3 platform.

III. Background

A. Deep Learning and Convolutional Neural Network

Deep Learning is a subset of machine learning. It learns features from the data and make prediction of unknown data based on its features. It consists of many layers. each layer is dependent on another layer. The output of one layer serves as input to the next layer. every layer will extract some features and send them to next layer.

The neural networks used in deep learning are inspired by the structure and function of the human brain. They consist of multiple layers of interconnected nodes (neurons) that process information and pass it on to the next layer. Each layer extracts increasingly complex features from the data, allowing the network to learn and recognize patterns.
CNN is a convolutional neural network widely used model for image data. CNN is somewhat differ compared to Basic neural networks it uses the convolutional layers. Where each layer predicts some features and sends to next layer. Each layer neurons are connected by weights and the weights are get updated with the help of back propagation algorithm.

In CNN model we will apply so many convolutional filters on the input image to learn/predict the features. And there are some Pooling layers which will try to reduce the computational power of model. In this paper we have applied CNN model for food classification problem.

B. Transfer Learning

Transfer learning is a technique as it says it is technique of transferring weights. Means once we trained a model, we can store the weights of that model and we can use those weights for another related task model. It offers great advantages that a model trained on millions of data for days/months/years can be stored. And in another related model we can simply use those already pretrained weights. So, the new model is no need to go through so many training epochs.

Even good amount of research is going on still there are many challenges involved in the prediction of nutrition in the food. And there are so many researchers has proposed their models for predicting the nutrition presence in the food. But most of the work is done on the similar data which is available openly. And there are some researchers done the nutrition estimation work on data which is specifically some region/place based. And to the best of knowledge there is no model is available to estimate the nutrition specifically the rooted Indian food. So, I have taken this challenge to estimate the nutrition in Indian food.

IV. Description of Data

Data is collected from Kaggle. Which is having 80 classes of 50 images in each class. And I have included 6 more classes into the data from Kaggle data. So total 84 classes with 50 images in each class are used for this project.

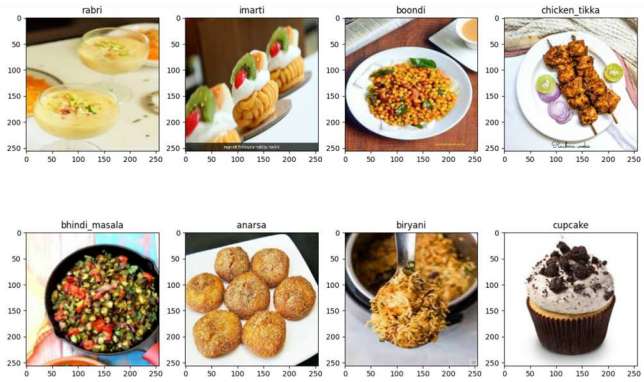


Figure 1: Some Random images from dataset

V. Nutrition Data Collection

And the nutrition data is collected by own from different sources of websites available. As the data related to Indian food itself is very less, so getting all foods nutrients data from a single source it not available. So, from different sources have collected the different foods nutrients data.
Some of the weblinks that the nutrients data collected is mentioned below.

- https://www.myfitnesspal.com/food/calories
- https://www.pcrm.org/good-nutrition/plant-based-diets/recipes/
- https://www.tarladalal.com/
- https://www.nutritionix.com/
- https://momamanipur.com/
- http://recipeofhealth.com/recipe/
- https://www.myfitnesspal.com/nutrition-facts-calories
- https://www.slurrp.com
- https://www.healthline.com/nutrition

SOME OF THE CHALLENGES WITH THE NUTRITION PREDICTION PROCESS

Just by looking the food item even the diet expert can't say the exact nutrition content. In this process the model is looking at the image and estimating the nutrition content so this process also can't predict the nutrition content exactly. Strictly speaking unless we chemically analyze the food, we can't get the exact amount of nutrition content. So we can't get the exact amount of nutrition content but defiantly it gives the close estimation of nutrition content.
And other challenges like in the food if there are high nutrition dense ingredients present which can't be able to see by naked eye means, it can't be seen by model also so there will be some nutrition estimation loss in those cases.
And every cook will not add the same amount of ingredients in the recipe so that will vary the nutrition content slightly. So can't get the exact amount of nutrition in the food but can get close estimation of nutrition content.
And these days there is creative food recipes are coming, in which traditional process of making the recipe is broken. there might be new ingredient added based on personal interest of the person. So, at that time there might be nutrition estimation loss.
And finding the nutrition per meal will only give an idea of nutrition user is consuming. But not gives the exact amount of nutrition present in the food.

VI. Proposed Work

Nutrition estimation in the food generally on top level follows 3 steps.

1. Recognizing the food item
2. Estimating the nutrition in the recognized image
3. Make a record of nutrition user is consuming.

So, for training the CNN model have taken the data which is openly available in Kaggle for Indian food image classification. So, in this data we will 80 classes of Indian food images in each class will have 50 images each. But for nutrition prediction in the 2nd step as mentioned above we need to have the nutrition information prior. So, after recognizing the food then have to map predicted image with the nutrition data for nutrition estimation. Then we need to record the nutrition content of the meal.
First the user will give the information about his/her like height, weight and age, gender, activity level goes through every day and name. so, from this information will calculate the user BMI and the nutrition requirement per day. Then once the user uploads the images of meals, he/she going to consume. From there will predict the food class and then will calculate the nutrition content per meal. Then will show the user about the

1. BMI
2. Nutrients needed per day
3. Visual bar graph of
    a. Nutrients going to consume with present meal
    b. Nutrients consumed till present meal
    c. Required Nutrients in the day

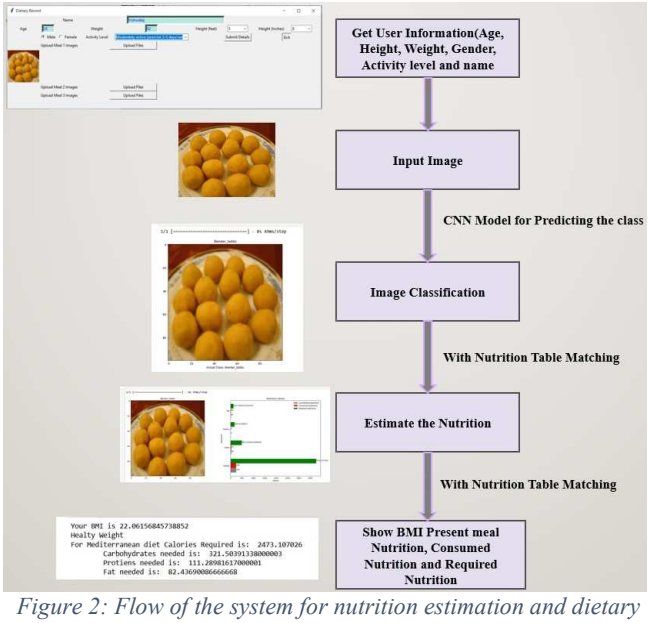


Figure 2: Flow of the system for nutrition estimation and dietary management

And the Indian food data available is not much. In this research paper have used the concept of data augmentation. Where we will generate new images by making some changes to the existing data images. So along with existing data will also use data augmentation to create a greater number of training samples. As we are taking the deep learning approach bigger the data size the model can learn better, so to increase the system performance we have considered augmentation approach. As food images can be seen from any angle, we can make rotation of images till 180 degrees also. And most of the images are symmetric in horizontal direction we can also flip the images in horizontally but not vertically because flipping the food images upside down makes no sense. Since most of food item in real world will not be flip vertically.

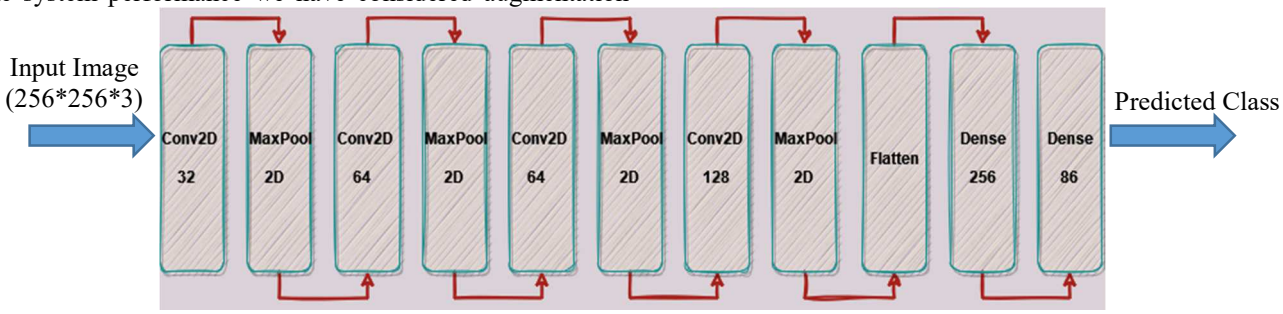


Figure 3: Convolutional model architecture used for classification of the food images

And have used 4 pretrained models on the data. To compare the accuracy of different models on the Indian food data. we have applied DenseNet201, InceptionV3, MobileNetV2 and Xception models on the data. And we didn't disturbed the pretrained model's architecture and used the same respective pretrained weights. Only changed the input layer dimension and added one Flatten layer and one Dense layer of 256 neurons. The input shape is (256,256,3) and the output layer with 84 neurons.

Model: Convolutional Neural Network

Our Model which implemented is of with 4 convolutional layers and 4 maxpool layers. Then at end of the layer added 2 dense layers with 256 neurons and output layer with 84 neurons (no. of prediction classes).

The model will estimate the nutrition contents per meal

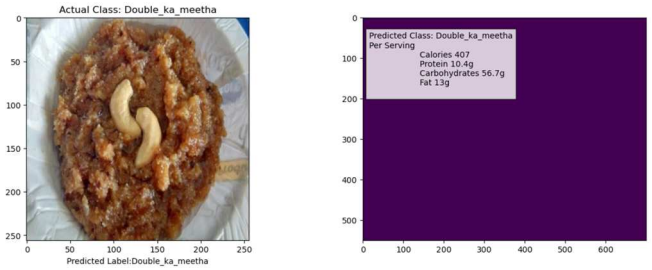
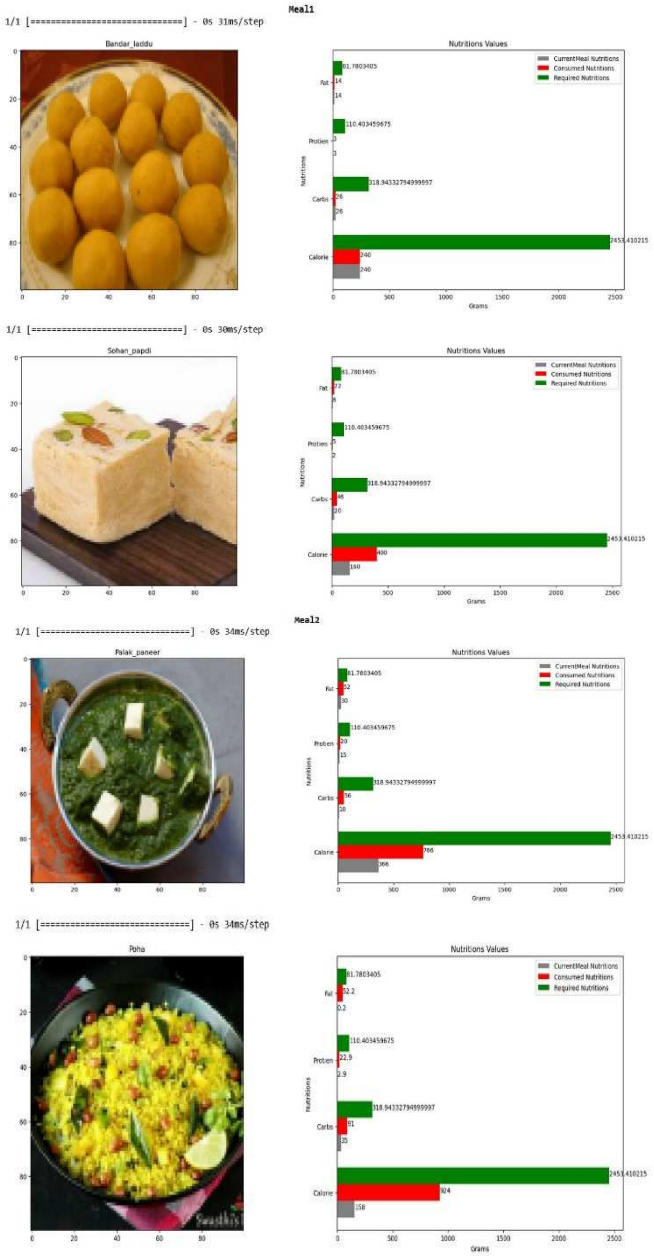


Figure 4: Nutrition Estimation

DIETARY MANAGEMENT

So the dietary management starts after the estimation of nutrition. The model built will give the present meal nutrition content. And from the user information we will get the required nutrition information per day. So we can keep a track of the nutrition content consuming, so at every meal will show 3 nutrition values

1. Nutrition content going to consume from the present meal
2. Nutrition already consumed in the day
3. Nutrition required per day.



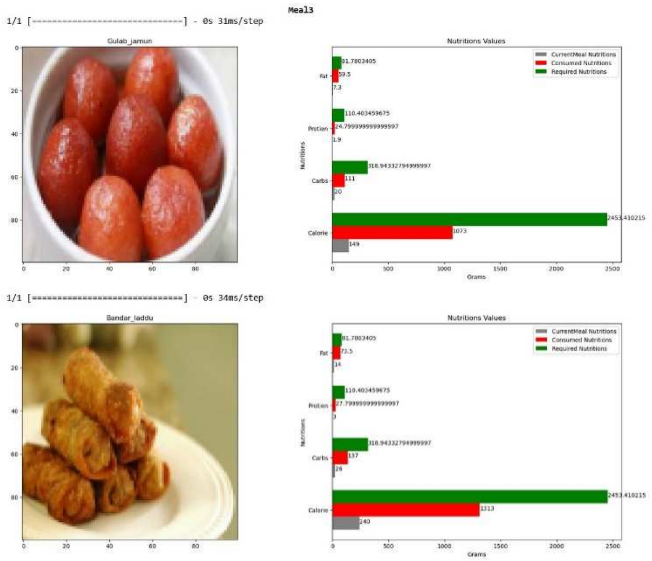


Figure 5: Nutrition estimation and dietary management of user meals

First, we Will collect the information from user like Name, Age, Height, Weight, Gender, and Activity level goes through. Based on this information we can calculate the BMI (Body mass index)

$$BMI = \frac{\text{weight(kg)}}{height(m)^2}$$

And a high BMI indicates high body fatness and lower means less Fat. The range for BMI of healthy weight is generally considered between 18.5 to 25.

Table I: BMI information

BMI	Weight Status
Below 18.5	Under Weight
18.5 – 24.9	Healthy Weight
25 .0 – 29.9	Over Weight
30.0 and above	Obesity

Calculating the nutrition requirement

Nutrition requirement per day is decided by the BMR (Basal Metabolic Rate).

This Paper followed the Harris-Benedict formula to find the user metabolic rate (BMR). User BMR is determined by some factors like age, gender, and height and weight. The BMR will give the information about how many calories needed by the user based on his age, gender, height and weight.

The Calorie requirement of user per day is calculated as follows:
Step1: Calculate the BMR
Step2: Calculate the AMR

BMR Calculation
For women:
BMR = 655.1 + (9.563 * Weight (kg)) + (1.850 * Height (cm)) – (4.676 * Age (years))
For men:
BMR = 66.47 + (13.75 * Weight (kg)) + (5.003 * Height (cm)) – (6.755 * Age (years))

AMR Calculation
It will calculate the is the amount calories needed per day based on the physical activity user is doing.

- Sedentary (little or no exercise):
  - AMR = BMR * 1.2
- Light activity (exercise 1-3 days/week):
  - AMR = BMR * 1.375
- Moderate activity (exercise 3-5 days/week):
  - AMR = BMR * 1.55
- Active activity (exercise 6-7 days/week):
  - AMR = BMR * 1.725
- Very Active activity (hard exercise 6-7 days/week):
  - AMR = BMR * 1.9

The AMR (Active Metabolic Rate) is the number of calories that a person needs to consume daily. and the AMR is telling about the required calories need to be consumed by the user to maintain the weight. If user need to increase the weight, then need to consume more calories than AMR Calculated, and if want to decrease the weight need to consume less calories than calculated AMR.

And the nutrition content calculated in this paper are Protein, Carbohydrates and Fat. As these 3 are the basic nutrients. So this paper followed Mediterranean diet which consist of 52% carbohydrates, 18% protein and 30% fat out of total calories.

Example a 24 years male with height 5 feet 5 inch and weight 62 kg with a moderate activity (exercise 3-5days/week) needs 2453.41 calories a day, carbohydrates 318.9 grams, 110.4 grams of protein and 81.78 grams of fat needed a day to maintain the weight.

Figure 6: Python Based GUI to take user captured images

```
Your BMI is 22.745607621392757
Healty Weight
For Mediterranean diet Calories Required is:  2453.410215
        Carbohydrates needed is:  318.94332794999997
        Protiens needed is:  110.403459675
        Fat needed is:  81.7803405
```

Figure 7: User Based Nutrients Calculation

VII. Results

The Image recognition System with CNN model for food classification is having validation accuracy of 92.53%

and train accuracy of 89.32%. we have Trained the model with 14 epochs on the data with Adam optimizer with its default learning rate (0.001). we can see a good accuracy even we didn't trained the model with huge data.

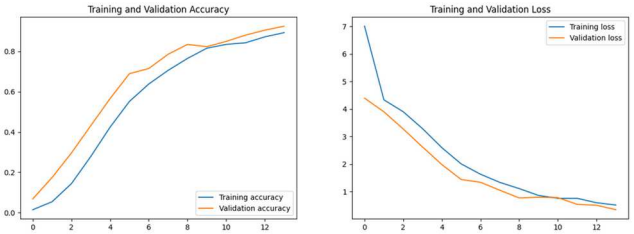


Figure 8: Accuracy graph (Left) and Loss Graph(Right) for every epoch

We can increase the epochs to get the even higher accuracy, but it is not recommended as I have seen after 14 epochs train and validation curves are getting closer. And still if we increase the epoch more than 20 it may lead to overfitting problem.

Overfitting is a problem because model is trained on the data very well leads to loss of generalization and gives less accuracy in testing time. As model will be over learned the features which are present in the data only, so when a test image came with even slightly different features model can't be able to predict accurately. So, leads to drop in test accuracy.

And the accuracy of different pretrained models on this data are:

Have the following accuracies. 4 pretrained models such as DenseNet201, InceptionV3, MobileNetV2 and Xception models are used on the data and their respective validation accuracy are 61.37%, 48.49%, 52.9%, 51.16%.

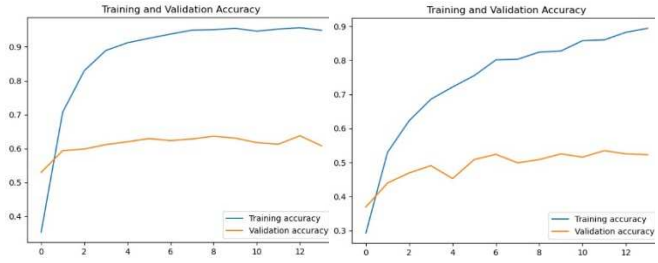


Figure 9: Train History of DenseNet201 (Left) and InceptionV3 (Right)

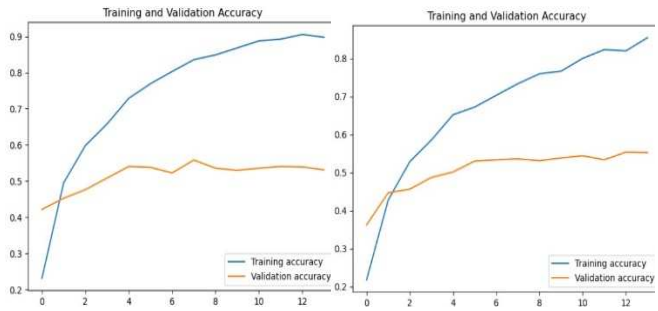


Figure 10: Train History of MobileNetV2 (Left) and Xception (Right)

Table II: All Models Accuracy

Model	Train Accuracy	Validation Accuracy	Test Accuracy
DenseNet201	0.9506	0.6271	0.6235
InceptionV3	0.8936	0.5226	0.4988
MobileNetV2	0.8977	0.5309	0.5689
Xception	0.8525	0.5499	0.5380
Our Model	0.8938	0.9187	0.9188

We can see there is a greater validation accuracy in our model compared all the pretrained models. This is mainly even the pretrained models are trained on huge data, the models are not encountered with rooted Indian food. And as our data itself specific to Indian food, data we had is very rooted Indian food. So the pretrained models are even trained on our data, those models are not giving higher accuracy, because we have added only 2 layers to the pretrained models because thought to not disturb the pretrained model's architecture.

VIII. Conclusion

This Paper Built Nutrition estimation in consuming meals and maintains the record of the nutrition. Model which is built and having good accuracy for estimating the nutrition in the Indian food. In this paper have explained about the Deep Learning approach, which followed to estimate the nutrition in the food. We have collected food data which available in Kaggle. And the nutrition data is collected by own from different sources. This approach for food identification has the good validation accuracy. And it maintains a record of nutrition consumption from present meal, consumed nutrition till present meal in the day and total required nutrients in a day based on the user age, height, weight, gender, and activity level goes through.

Future scope of this work can be done in the way of improvising the model such that we can suggest the next meal for the user based on the present meal nutrition. Example: If in present meal user is consuming less protein food then we can suggest the user some protein rich food items for next meal.

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