A PBL REPORT

On

"DETERMINATION OF BODY MASS INDEX USING FACIAL IMAGES"

By **GD 8**

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Certificate

This is to certify that the PBL report entitled

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is approved by ***Prof. Rahul Pitale*** for submission. It is certified further that, to the best of my knowledge, the report represents work carried out by my students as the partial fulfillment for S.E. Computer Engineering (Semester II) Laboratory Work as prescribed by the Savitribai Phule Pune University for the academic year 2020-21.

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Abstract and Keywords

Abstract— The Body Mass Index (BMI) is the widely used tool for assessing a person's health. It has been used to determine if a person is underweight, normal body weight, overweight, or obese. BMI is linked to fat mass and is an important predictor of illnesses that may arise as a result of increased body fat levels. With a greater calorie diet and a reduced activity lifestyle, increased body fat is more common these days. People and communities can use the BMI to determine their nutritional condition as adults. We suggest a time and money effective approach of calculating Height, Weight, and BMI from a person's face, given that people have less time in their busy lives and most individuals do not have a weighing machine and/or a measurement tape.
In this report, we use propose a machine learning model to accurate predict a person's height, weight and Body Mass Index by the use of facial image. We begin by utilising a Deep Neural Network architecture – ResNet34 – to recognise the face in a picture. The Feature Extractor model is given the picture. The collected characteristics are fed into a regression model, which predicts the height, weight, and BMI. The "VIP Attributes" dataset, which comprises 1026 people with their associated Height, Weight, and BMI, was used to test our model. The Support Vector Regressor model with both basic parameters and hyper-parameter tweaking had the greatest performance for BMI.

Keywords

1.	BMI	Body Mass Index
2.	ML	Machine Learning
3.	AI	Artifiacial Intelligence
4.	DNN	Deep Neural Network
5.	CNN	Convolutional Neural Network
6.	ANN	Artificial Neural Network
7.	OpenCV	Open Computer Vision
8.	Regression	Regression Analysis
9.	SVM	Support Vector Machine
10.	SVR	Support Vector Regression

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1. Introduction

1.1 Problem Definition

1.1.1 To create an effective way of estimating the height, weight, and Body Mass Index of an individual through facial features using image processing, machine learning, and deep learning models.

1.2 Goals and Objectives

1.2.1 To research in the domain of Machine Learning and Image Processing.

1.2.2 Acquire knowledge in how to detect the face and its expression using computer vision.

1.2.3 Analyse the Facial features and use them in determination of Body Mass Index (BMI), height and weight of human being.

1.2.4 Collate the four Regression models of supervised learning algorithm of machine learning.

1.3 Motivation

1.3.1 Weight is a pertinent indicator for health and excessive weight has been associated with obesity, diabetes, and cardiovascular diseases.

1.3.2 Height and weight are used in surveillance, forensics and image retrieval systems.

1.3.3 Body weight and height have been soft biometric traits in automated biometric systems.

1.4 Scope of work

1.4.1 Easy and Effective way to calculate BMI

1.4.2 Diagnose overweight and obesity.

1.4.3 Identify different health parameters and future disorders.

1.4.4 Create soft biometric datasets for security and forensics.

1.4.5 Fitness tracking of an individual.

1.5 Outcomes

1.5.1 Thorough research in the domain of Machine Learning and Image Processing.

1.5.2 Gained insight into facial image processing

1.5.3 Analyse the Facial features and use them in determination of Body Mass Index (BMI), height and weight of human being.

1.5.4 Learning and comparing different regression techniques widely used in the machine learning community.

2. Literature Survey

2.1 Summary of Literature Review:

2.1.1 Comparison of our project with existing survey papers:

- In the below-mentioned first paper, for BMI inference from face pictures, they examined and compared the performance of five alternative Convolutional Neural Network architectures: VGG19, ResNet50, DenseNet, MobileNet, and light CNN. They used three datasets that were freely available online.
- VisualBMI, VIP-Attributes, and Bollywood datasets are BMI annotated face picture datasets gathered from social media. ResNet50 was used to demonstrate the efficiency of deep learning approaches in inferring BMI from face pictures with the lowest Mean Absolute Error.
- In the below-mentioned third paper, they created a novel algorithm for detecting the face and facial characteristics that can reliably locate the eyes and mouth in pictures. A mixture of the image's brightness, colour, and edge characteristics is employed in their technique. This technique has been built and tested on a database of 103 distinct face pictures.The method has shown an accuracy of 91%.
- The fourth study, cited below, suggested using image processing and pattern recognition approach to detect human faces and facial characteristics from colour pictures. A Gaussian skin-color model was used to separate a colour picture into skin and non-skin areas. Noise reduction and hole filling were achieved using mathematical morphology and region filling approaches. They used an elliptical model to approximately locate the eyes and mouth regions, and then classified them using the support vector machine (SVM). Face detection was 96.7 percent accurate, while facial feature extraction was 90.0 percent.
- In the fifth paper, they developed a unique model utilising Convolution Neural Networks (CNN) and Artificial Neural Networks in the fifth publication stated below (ANN). Using the Viola-Jones method, they were able to recognise the face in a picture. They used the Reddit-HWBMI dataset and the Face-to-BMI dataset. They implemented face extraction using the XceptionNet model and VGG-Face (Resnet model).
- Our project used a face recognition library to recognize faces and extracted facial features using facenet pre-trained architecture. Linear regression, Logistic Regression, and support vector machine (SVM) models have trained with the DigitalDigitalVIP attributes dataset. All models are trained, scripted in the python programming language. The editor used is Jupyter notebook.

2.1.2 Comparison of 5 Survey Papers:

Reference 1	AI-based BMI Inference from Facial Images: an application to Weight Monitoring
Objectives	Self-diagnostic image-based methods for healthy weight monitoring
Proposed Solution	Used CNN Five architectures, VGG19, ResNet50, DenseNet, MobileNet, and light CNN
Results	Average MAE ranges from [1.04, 6.48] in an observational study of three publicly available face picture datasets. Because of differences in BMI annotation and sample size, the findings differed among datasets. DenseNet and ResNet obtained superior performance over other nets.
Advantages	Mean absolute error in a good range. Greater accuracy.
Limitations	The time and cost required is more than usual

Table 2.1- Summary of paper 1

Reference 2	A novel method to estimate Height, Weight, and Body Mass Index from face images
Objectives	A method for calculating height, weight, and BMI from a person's face that saves time and money.
Proposed Solution	The Viola-Jones method is used to detect the face in a picture. Used CNN and ANN models to estimate height, weight, and BMI.
Results	When employed as a Feature Extractor, the XceptionNet model provided the greatest performance for BMI. The XceptionNet also outperformed the VGG-Face (Resnet model) in terms of weight, while the VGG-Face (Resnet model) outperformed the XceptionNet in terms of height.
Advantages	A considerable better and accurate method to estimate BMI
Limitations	The performance of the models can be tuned.

Table 2.2- Summary of paper 2

Reference 3	Facial Recognition using OpenCV
Objectives	To improve the accuracy of face detection and recognition techniques.
Proposed Solution	To apply pre-filters before the image is sent for detection and recognition. Using OpenCV apply haar cascade filter which increases the detection quality.
Results	Considerable better accurate results were found and appended the authentication of the face in the frame.
Advantages	A more accurate way for detection and recognition.

Limitations	Need more train images from different angles and hard to synchronize all the images and make a single image per person.

Table 2.3- Summary of paper 3

Reference 4	Detection of Face and Facial Features in Digital Images and Video Frames
Objectives	Use them in Human-Computer Interaction to investigate the detection system of the face and frontal characteristics such as the eyes and lips.
Proposed Solution	A unique method for detecting the face and morphological features is proposed, which can properly locate the eyes and mouth in pictures. This approach employs a mix of the image's brightness, colour, and edge characteristics.
Results	The studies, which were conducted on a database of 103 pictures, revealed that employing edge information in conjunction with colour and intensity measurements to detect eyes can improve the accuracy and robustness of the judgement by 91.6 percent.
Advantages	Very high accuracy of the face and facial expression detections. Eyes and mouth can be used as soft biometrics.
Limitations	The image with low exposure is hardly detected.

Table 2.4- Summary of paper 4

Reference 5	Extracting Faces and Facial Features from Color Images
Objectives	To extract facial features and facial characteristics from colour pictures, proposed image analysis and pattern identification algorithms.
Proposed Solution	Classified skin and non skin region. Detected the size and shape of skin area. Roughly marked eyes and mouth. Used svm to classify features extracted from image.
Results	Technique performed 97% accuracy in face detection and 91% in features extraction.
Advantages	Detected many faces in one frame. Tracked faces of different sizes with ease.
Limitations	Merging of two faces. Dark image cannot detect human face.

Table 2.5- Summary of paper 5

3. SOFTWARE REQUIREMENTS SPECIFICATION

3.1 FUNCTIONAL REQUIREMENTS:

- User
  - A proper image input, either from a saved file of image capture from the existing hardware
  - Only a single user at a time per system.
- Hardware requirements (Desktop or Laptop of minimum specification)
  - i3 x86/64-bit processor
  - 2 GB RAM
  - 1 GB disk space
- Software requirement
  - Python programming language interpreter
  - Anaconda platform
  - Jupyter notebook
  - Sk-learn machine learning models
  - Facenet architecture

3.2 NON-FUNCTIONAL REQUIREMENTS:

3.2.1 Performance Requirements:

- The ability to correctly estimate the BMI of a given input.
- The response time of the model should be less.
- Faster than complex models which may require more time.

3.2.2 Security Requirements

- Image input will be protected in the algorithm and cannot be retrieved by any
- another different user.
- The generated output of the software will be accessed by the current user only.

4. System Design

4.1UML Diagrams:

4.1.1: Structural Diagram: Class Diagram

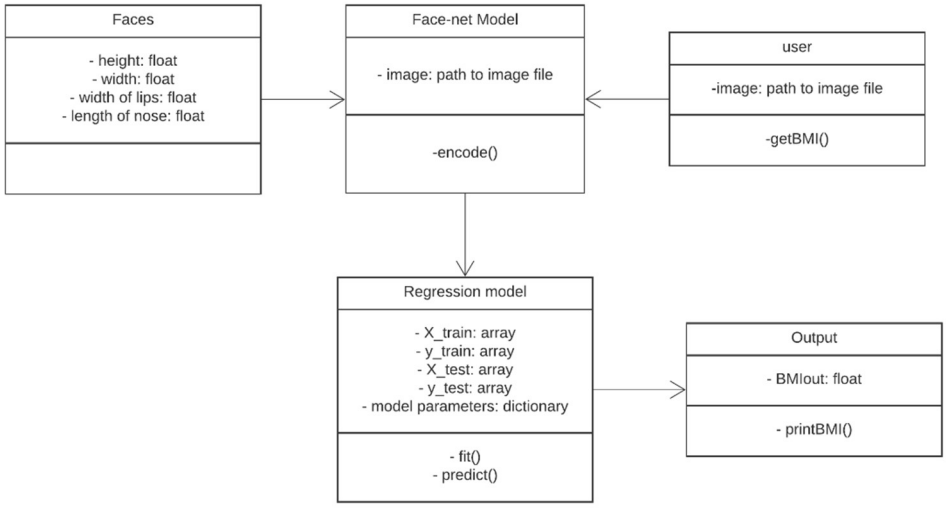

Figure 4.1 Class Diagram for Project

Description of class diagram:

1. Faces
   This class stores information of facial images required to train the machine learning model
   a. attributes
      i. height- stores the height of the face
      ii. width- stores the width of the face
      iii. width of lips- stores width of lips
      (And many features of the face)
2. Face-net model
   This class uses information from an image and encode the features into machine-readable language
   a. attributes
      i. image- stores the path of the facial image
   b. methods
      i. encode ()- encodes the facial features into machine-readable language
3. Regression model
   This class employs regression models on the train, test data as well as unknown inputs.
   a. attributes
      i. X_train- stores training data of encoded image data
      ii. y_train- stores independent variables of image data
      iii. X_test- stores testing data for regression models
      iv. y_test- stores values that will map to testing data
   b. model parameters- stores coefficients of model equations when hyper-

parameter tuning is applied

c. methods
    i. fit ()- trains the model
    ii. predict ()- for checking the accuracy and to output values for unknown data

4. user
   This class takes user input for an image
   a. attributes
      i. image- stores image file or path to image file
   b. methods
      i. getBMI()- will get the input from the model
5. Output
   This class will output the BMI predicted from the model
   a. attributes
      i. BMIout- stores the predicted BMI
   b. methods
      i. printBMI()- will print the BMI for the user

4.1.2 Behavioral Diagram: Activity Diagrams

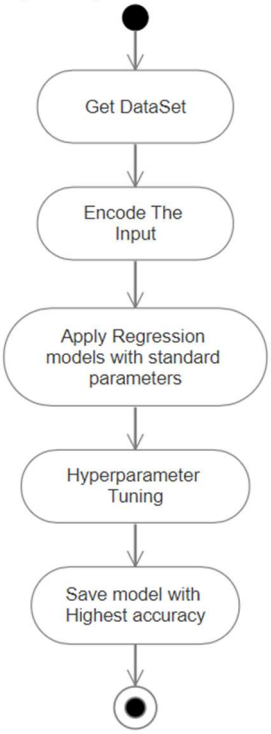

Fig 4.2 Activity Diagram for Training Model

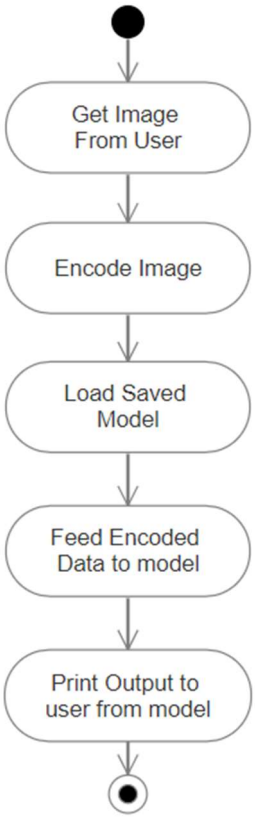

Fig 4.3 Activity Diagram for Unknown Image

5. Algorithmic Study

5.1. Study of Algorithms:

5.1.1. Linear Regression

Linear Regression is a supervised machine learning algorithm with a constant projected output and a consistent inclination.

5.1.1.1. Simple regression

The standard slope-intercept form is used in simple linear regression, where m and b are the variables in our algorithm. $Y = mx + b$

5.1.1.2. Multivariable regression

w represents weights of the different independent variables

$Y = w1x1+w2x2+w3x3$

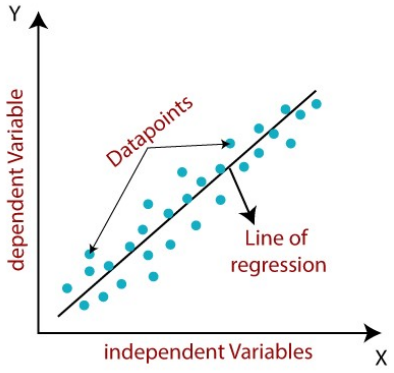

Fig 5.1 Linear Regression

5.1.2. Ridge Linear Regression

- Ridge regression is a model optimization technique for multicollinear data analysis. L2 regularisation is used in this procedure.
- Ridge Regression penalty is the degree of bias introduced into the model. This penalty term can be calculated by multiplying the squared weight of each individual feature by the lambda.
- When there is a lot of collinearity between the independent variables, a general linear or polynomial regression will fail, then Ridge regression can be employed to tackle the problem.

$$L(x, y) = \text{Min}\left(\sum_{i=1}^{n} (y_i - w_i x_i)^2 + \lambda \sum_{i=1}^{n} (w_i)^2 \right)$$

5.1.3. Lasso Regression

- Another regularisation technique for reducing model complexity is lasso regression.
- It's analogous to the Ridge Regression, but instead of a square of weights, the penalty term simply contains absolute weights.
- As it uses absolute data, it can reduce the slope to zero, whereas Ridge Regression can only go close to 0.
- L1 regularisation is another name for it. The Lasso regression equation will be

$$L(x, y) = \text{Min}\left(\sum_{i=1}^{n} (y_i - w_i x_i)^2 + \lambda \sum_{i=1}^{n} |w_i| \right)$$

5.1.4. Support Vector Regression

- Kernel: It's a mapping function that converts lower-dimensional data into higher-dimensional data.
- Hyperplane: In general, SVM is a way to differentiate two classes, but in SVR, it is a line that aids in the prediction of continuous variables and covers the majority of data points.
- Boundary line: Besides the hyperplane, boundary lines are the two lines that establish a margin for data points.
- Support vectors: The data points closest to the hyperplane and opposite class are called support vectors.

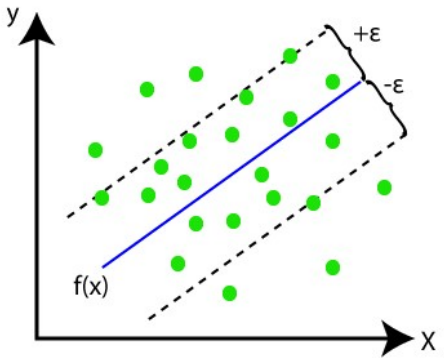

Fig 5.2 Support Vector Regression

6. Advantages, Disadvantages, and Applications

6.1. Advantages / Merits:

- 6.1.1. No requirement for actual measurement of body features
- 6.1.2. Automated method without possibility of human error
- 6.1.3. Easy creation of soft biometrics through facial features only
- 6.1.4. Faster than artificial neural networks

6.2. Disadvantages:

- 6.2.1. Cannot achieve more than 99% accuracy
- 6.2.2. Processing speed dependent on system efficiency

6.3. Applications:

- 6.3.1. Can be extended for use in image retrieval system
- 6.3.2. Can medical treatments
- 6.3.3. Can be used in physical fitness training regimes

7. Conclusion

- Regression model gives considerable accuracy and faster than complex neural networks.
- The models fail to give the correct height and weight for the dwarf humans.
- We found no substantial gender bias when calculating BMI, height, or weight.
- The present demand for self-diagnostic tools for remote healthcare, as well as for soft biometrics classification in security applications, inspired the development of the height, weight, and BMI estimator.
- Support Vector Regression gives highest accuracy.
- Linear Regression performs poorly if no regularization is applied and gives the worst accuracy among all regression techniques which is less than 20%.

	Linear Regression	Ridge Regression	Laaso Regression	Support Vector Regression
Accuracy(in %)	18.01	97.11	96.14	97.17
After Hyper-Parameter Tuning(in %)	-	97.15	97.11	97.21

Table 7.1 Accuracy Comparison of Regression Models

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