iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare

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Outline of the Talk

- Introduction & Motivation
- Related Prior Works & their Issues
- Addressed Research Question & Proposed Solution
- Method
- Results
- Conclusions & Future Work

Introduction

- **Internet of Things**
  - The Internet of Things is a network of devices where each device in the network is recognizable and connected.

- **Internet of Things**
  - The Internet of Medical Things is a network of medical devices where each device in the network is recognizable and connected.

Imbalance Diet is a Global Issue

- Imbalanced diet can be either more or fewer of certain nutrients than the body needs.

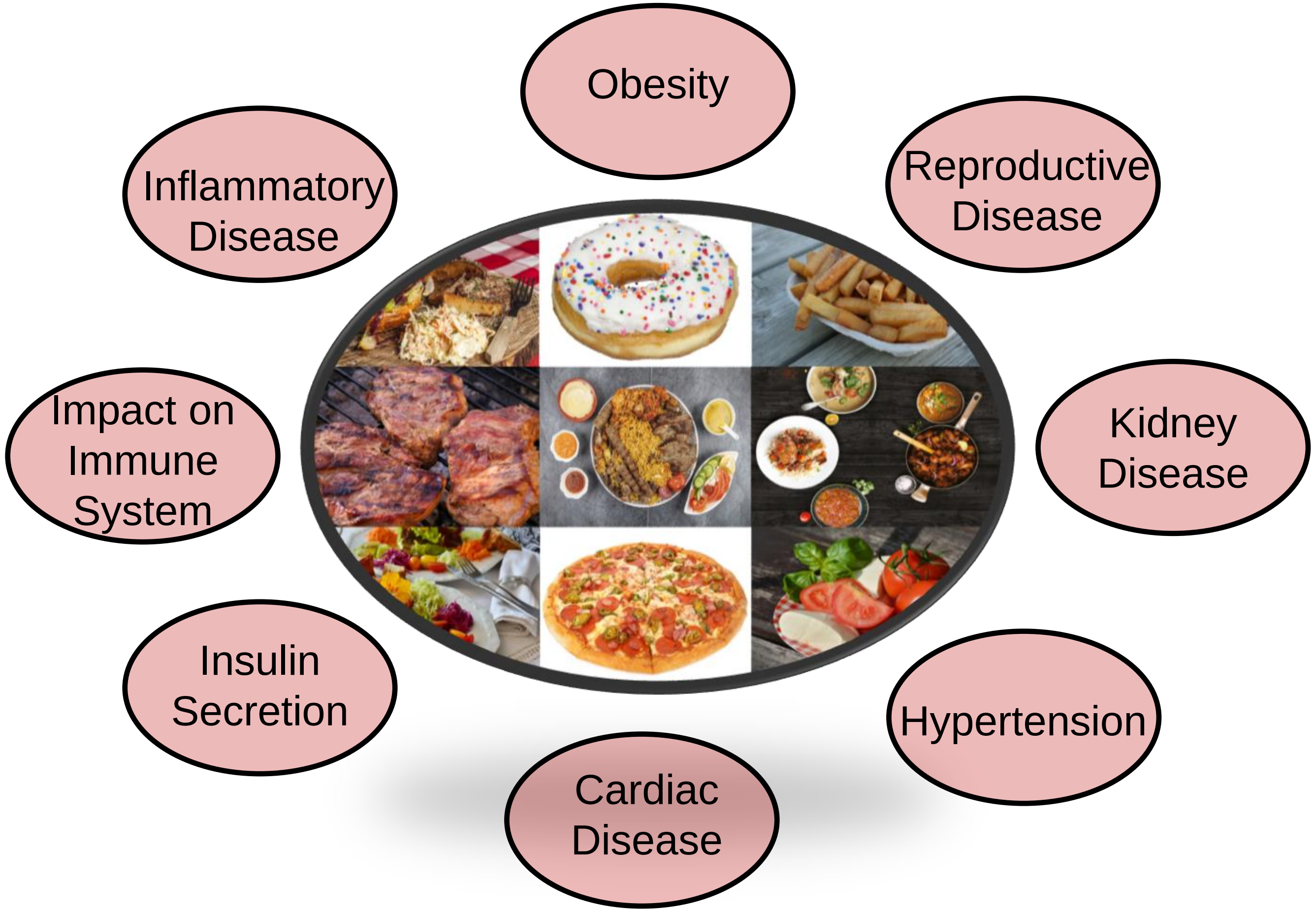
- In 2017, 11 million deaths and 255 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors.

- Eating wrong type of food is potential cause of a dietary imbalance.

Source: S. P. Mohanty, OCIT 2021 Keynote, 16 Dec 2021

Motivation

- Food provides nutrients to our bodies.
- Our health suffers for lack of nutrition or the wrong ingredients.
- Overeating or not eating enough leads to weight gain, malnutrition, and chronic disorders.
- Obesity and inflammation cause most diseases.



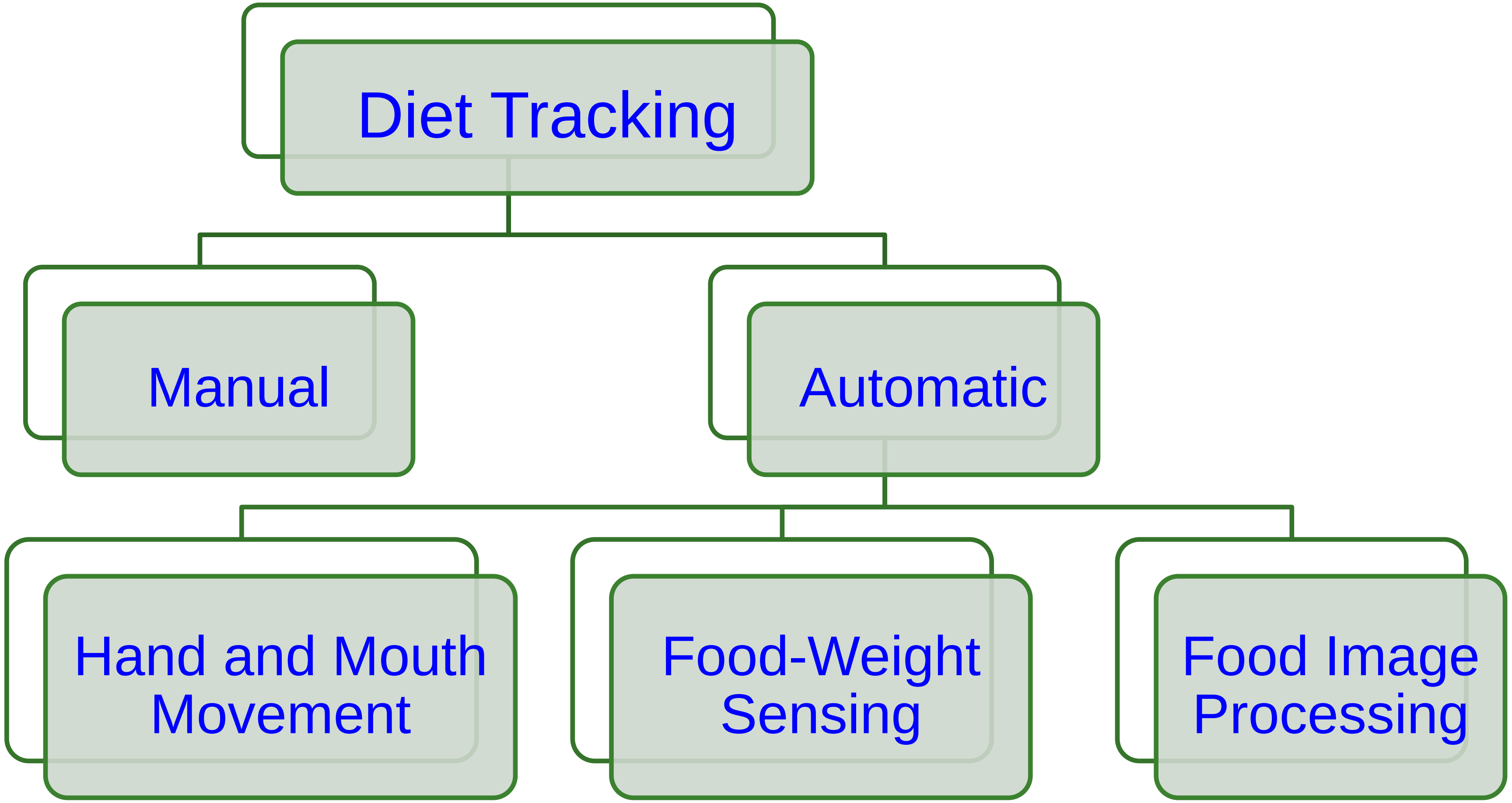
Motivation (Contd..)

- Processed foods, refined sugar, salt, trans fat, chemicals and preservatives, and food color cause obesity, inflammation, cardiovascular diseases, and diabetes.
- People are changing their diets to address these challenges.
- Diet control is a concern for everyone.
- Diet management involves balancing what you consume and how you track it.

Related Prior Works

Works	Year	Method	Nutritional Value
Liu, et al	2018	Edge-cloud approach, from food images, CNN, Food-101 dataset.	No
Pouladzadeh, et al.	2014	Cloud Support Vector Machine with Map Reduce technique, Calories for before eating and also with the leftover food.	No
Chel, et al.	2021	CNN for food classification and ingredient recognition.	No
Hussain, et al.	2022	A piezoelectricity-based wearable system.	No
Kumar, et al.	2021	Multi Layer Perceptron Model.	No
Rachakonda, et al. - iLog 1.0	2020	Object Detection and from food images.	Calory Only
Mitra, et al. (Current Paper - iLog 2.0)	**2022**	**Object Detection (SOA) , from Images, Food Quantification.**	**Yes**

Diet Tracking Approaches



Source: S. P. Mohanty, ICAISC 2022 Keynote, 03 Dec 2022

Food Tracking Apps

Table 1. Overview of popular food tracking approaches and their capabilities.

App Name	Downloads	Reviews	Rating	Image	Food-Label in Image			Manual	Scanning	Speech	Database search	Calories	Nutrition
				Input Method									
					Auto	Manual	Crowd Sourced						
MyFitnessPal	50 M	2 M	4.6					X	X			X	
FatSecret	10 M	268 k	4.5					X	X			X	X
My Diet Coach	10 M	144 k	4.4					X				X	
Lose it	10 M	77 k	4.4	X				X	X			X	
MyPlate	1 M	31 k	4.6					X	X			X	X
mynetdiary	1 M	31 k	4.5					X				X	X
Macros	500 k	3 k	4.5					X	X			X	
Cron-o-meter	100 k	1 k	4.2					X					
Eating Habit	100 k	549	4	X		X						X	
21 day Fix	100 k	470	3.7					X				X	
Bite Snap	50 k	2k	4.7	X								X	X
MealLogger	50 k	225	3.5	X				X				X	X
EatRight	10 k	220	4.5					X				X	
Keto Meal Plan	10 k	19	2.6								X		
YouAte	10 k			X									
KudoLife	1 k	11	3.4								X	X	X
Calorific	19		3.2								X		
Ate				X				?				?	?
Foodlog				X	X			X				X	

Source: S. P. Mohanty, ICICA 2022 Keynote, 26 Nov 2022

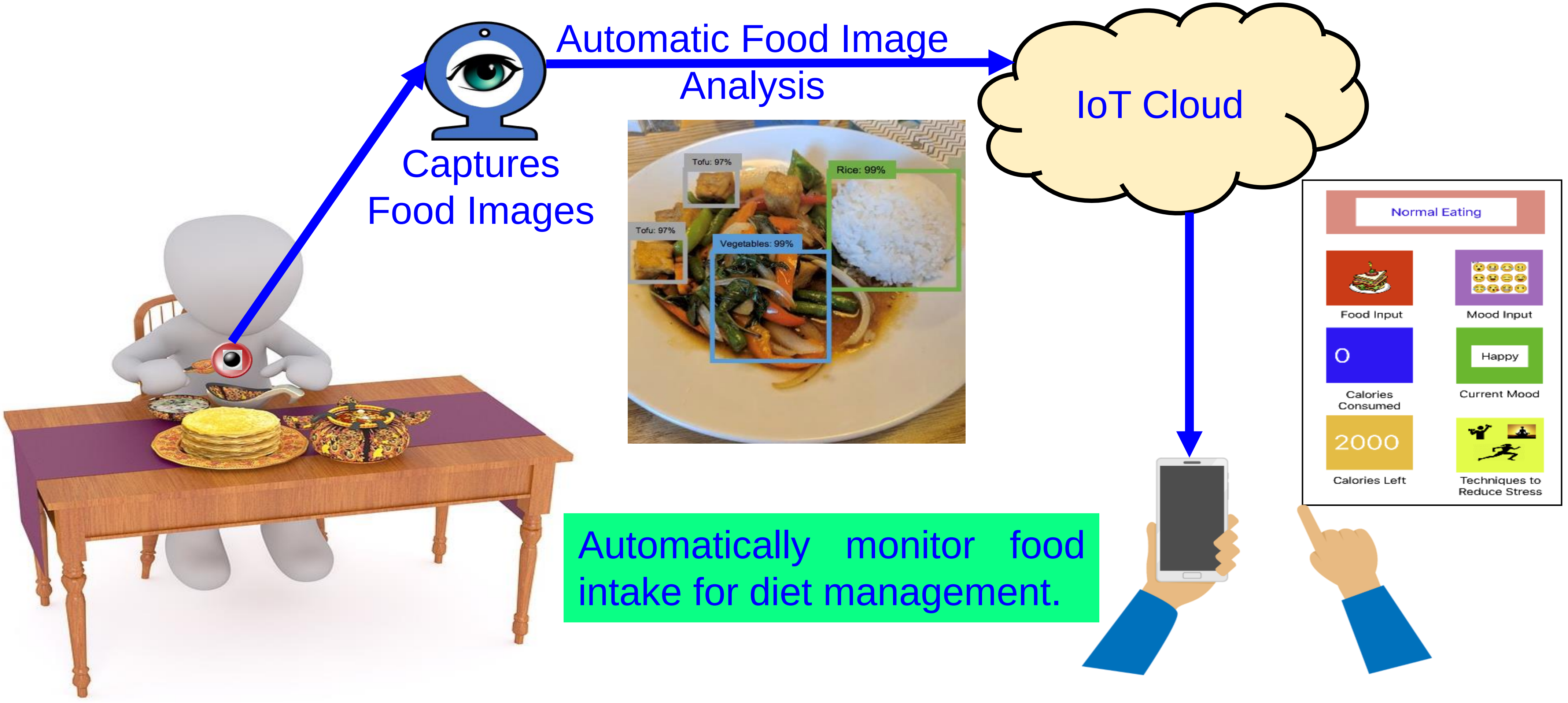
Issues with Current Solutions

- Majority of the food intake monitoring systems are heavily dependent on user inputs.
- Manual input is needed to quantify the food intake.
- Quite laborious and time-consuming, causing consumers to avoid using these systems for extended periods of time.
- As user-provided inputs dependent, oftentimes users provide inaccurate data so generates wrong results.

Not Addressed Features in Existing Works

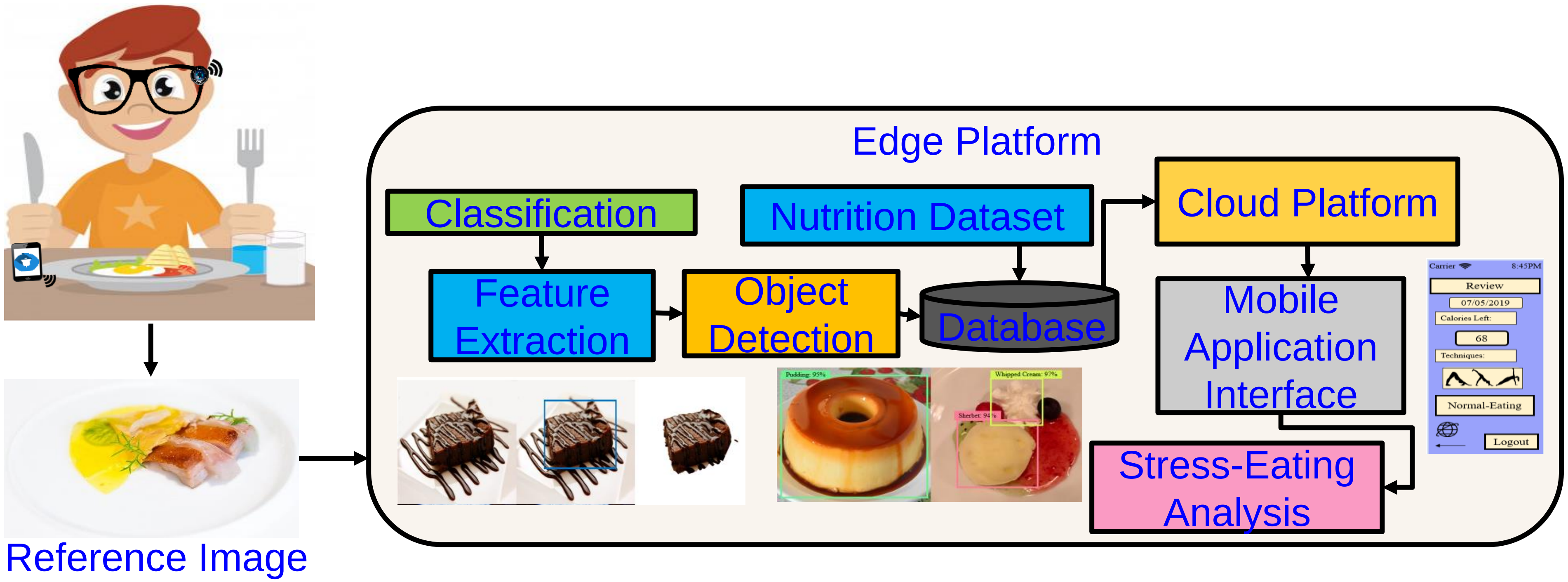
- Goals of these solutions are a balanced weight and a related diet.
- Mostly provide calorific value of the food.
- However, low calorie consumption $\neq$ a healthy diet.
- People with high blood pressure need a low salt diet, diabetic patients must maintain a no sugar diet, people with inflammatory diseases should follow an anti-inflammatory diet and so on.

Automatic Diet Monitoring & Control - Our Vision



Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

Our iLog 1.0 - Smart Healthcare - Diet Monitoring



iLog 1.0 - Fully Automated Detection System with 98% accuracy.

Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, “iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT”, *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

Our iLog 1.0 - Smart Healthcare

The data collected is sent to the Firebase Database in which the calorie count is generated by using a dataset with calories and sugars count of individual items from data.gov.

Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

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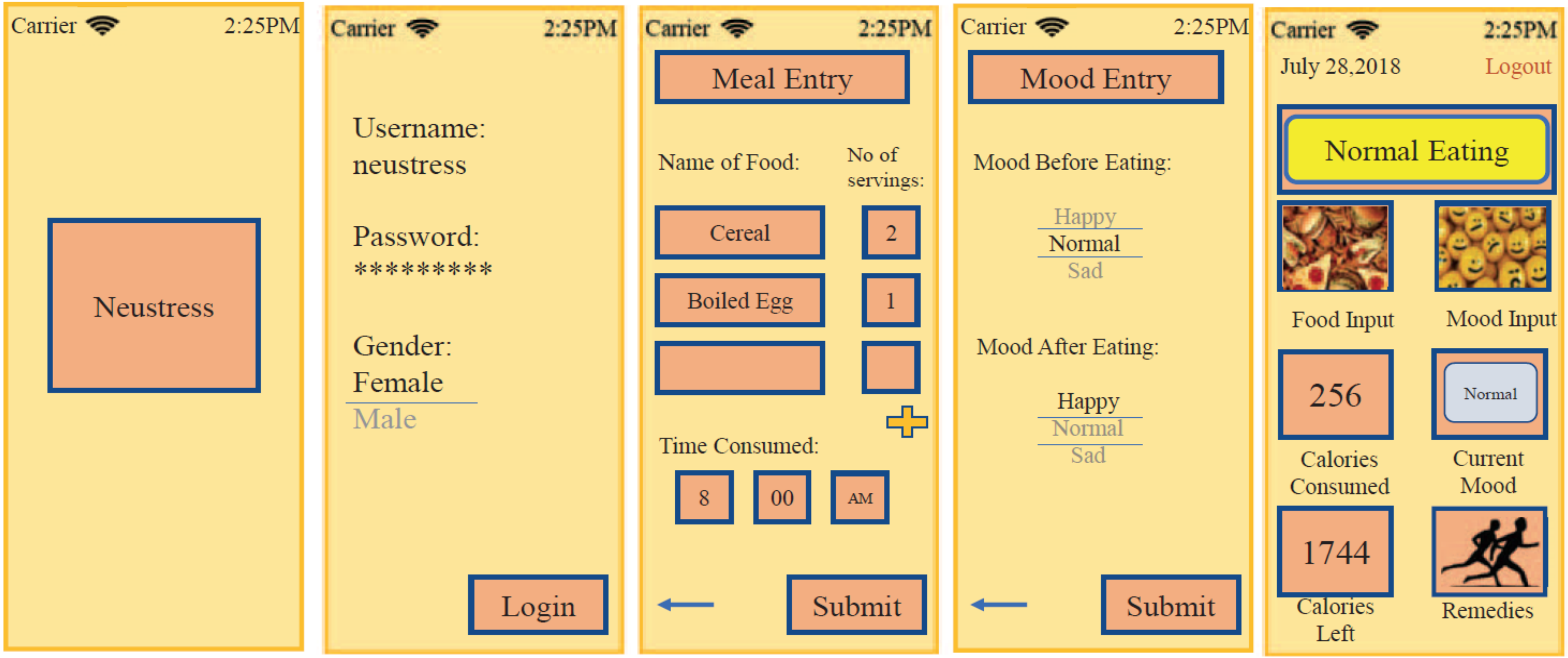

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Research Problem – iLog 2.0

How to track nutritional values- sugar, sodium, saturated fat, carbohydrates, and protein- of a food plate in real time?

Proposed Solution: iLog 2.0

- We propose iLog 2.0, a novel system to automatically estimate the nutritional value of food.
- It is an advancement of iLog 1.0 where the food calorific value was measured.
- Here, a full assessment of the saturated fat, cholesterol, sugar, sodium, protein, and carbohydrates of the meal has been performed with the state-of-the-art object detector which runs on the edge device.
- A holistic approach to food has been provided.

Novelties of iLog 2.0

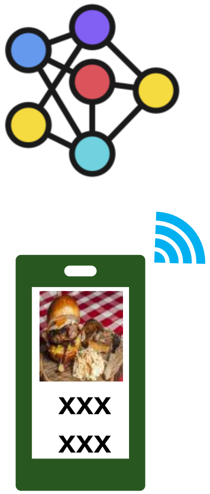
- It is a totally automated food nutrient tracking system. The user only needs to take an image of the platter.
- Automatic food quantification from image.
- Provides total nutritional value.
- It is completely personalized. The user can set a predetermined goal as prescribed by the doctor in addition to the standard target.
- Works at the Edge Platform.
- Mobile App has been made.
- It is a real-time estimation that gives the user an idea of the food's nutrients before eating.

System Overview of iLog 2.0

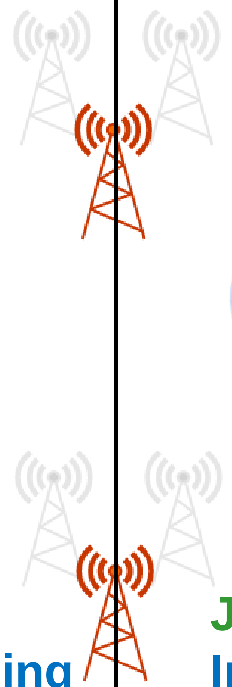
Smart Phone Camera (End Platform)

Job:
Image Acquisition

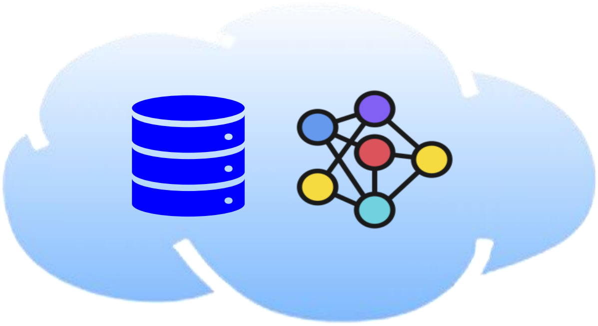
Smart Phone (Edge Platform)



Job:
Image Preprocessing
Object Detection
Food Quantization
Decision



nuTRILog Cloud Server (Cloud Platform)



Job:
Image and Label Storage
Fine-tune of the Model

Process Workflow of iLog 2.0

Photo Taken

↓

Object Detection

↓

Detection Result Sent to the Cloud

↓

Nutritional Value for Predetermined Portion Size Sent to the Device

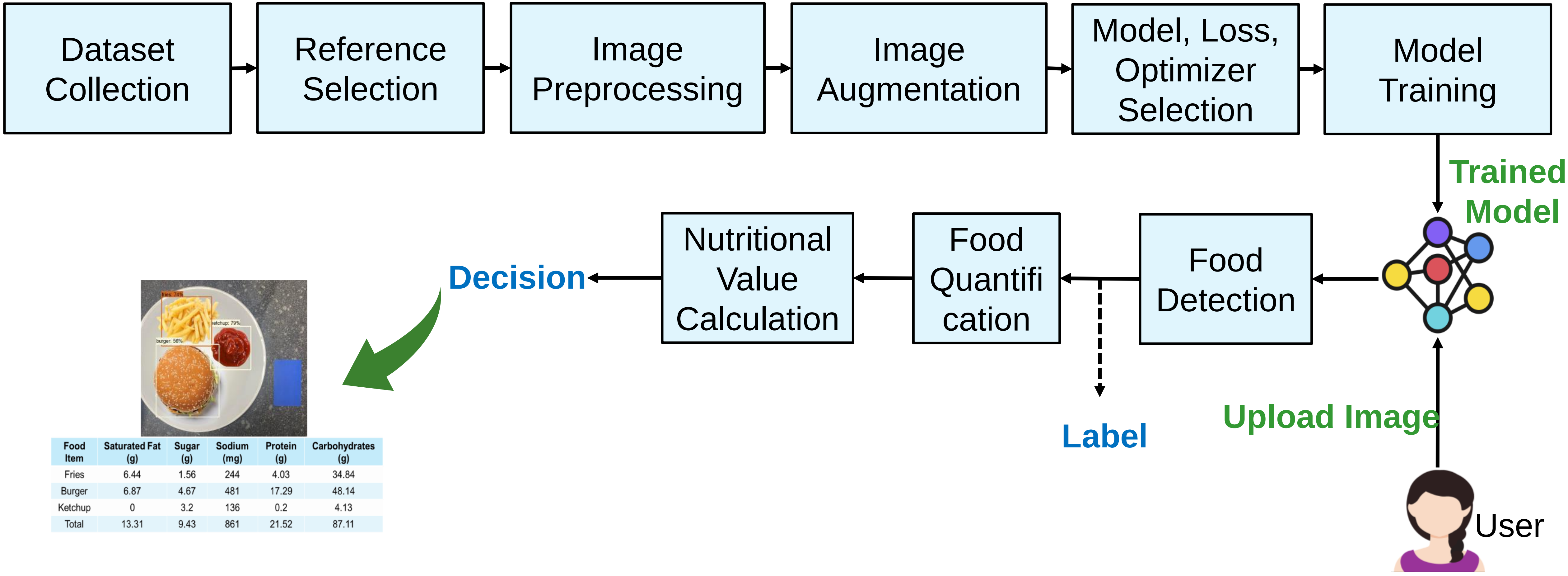
↓

Food Quantification

↓

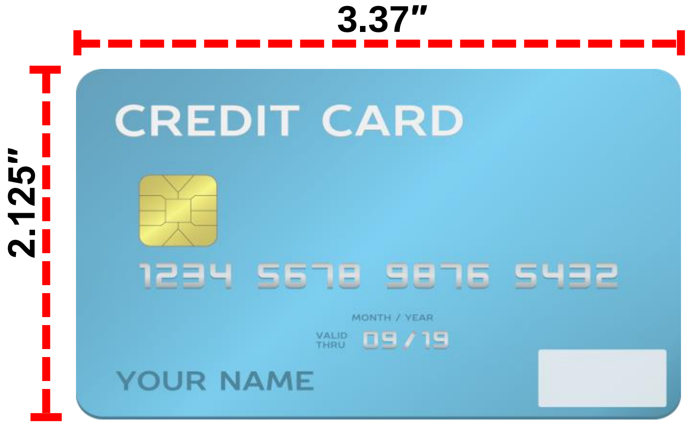
Nutritional Value Calculation

Development Workflow of iLog 2.0



Food Item	Saturated Fat (g)	Sugar (g)	Sodium (mg)	Protein (g)	Carbohydrates (g)
Fries	6.44	1.56	244	4.03	34.84
Burger	6.87	4.67	481	17.29	48.14
Ketchup	0	3.2	136	0.2	4.13
Total	13.31	9.43	861	21.52	87.11

iLog 2.0: Process of Detecting the Reference Card



Algorithm 1: Process of Detecting the Reference Card.

1: Set the color of the card.
2: Transform the image from RGB to HSV color space.
3: Calculate the card's rectangular area.
4: Find the ratio between card's true size to the image size.
5: Find all the contours.
6: Select the card's contour.
7: Determine Minimum Bounding Box.
8: Length and Width of the Bounding Box are Noted.

iLog 2.0: Process of Quantifying the Detected Food

Testing Image

Take a photo of a plate of food along with the reference card beside from the top angle.

Pass the image through the food detection model to obtain bounding boxes of detected food on the plate.

Card area with respect to the image is measured using Algorithm. 1.

Calculate ratios of the actual length (8.56 cm) and width (5.39 cm) of the reference card to the pixel length and width of the detected card in the photo.

Multiply the length and width of the bounding box of the detected food with the ratio to find the actual dimensions of the detected food.

Based on the detected food class, use the preset generalized height of the food.

Calculate the total volume *length* × *width* × *height* cm^3 of the detected food.

Multiply this volume by a constant of 0.8 to achieve a more accurate representation of the volume of food (accounting for extra area resulting from the rectangular bounding boxes).

Then, using the gram to cubic centimeter conversion for the specific food (ex: Rice - 0.87 grams per cubic centimeter, Ice Cream – 0.96 grams per cubic cm), determine the amount of grams of food that are present on the plate.

Finally, extract the corresponding nutritional value using the Food-A-Pedia database.

Food Nutritional Value

Dataset Details

- Food classification uses a modified customized dataset.
  - Some images are from Food-101
  - Some are downloaded from Google Images.
- 15 classes are from Food-101.
- LabelImg annotates the images with bounding boxes.
- 1500 training photos and 374 test photographs from **19** classes were used.
- **Classes**: Apple pie, beer, Bolognese pasta, bread, burgers, carbonara pasta, Chantilly cake, coffee, cream, fries, hot dogs, ice cream, ketchup, omelet, pie, potatoes, rice, salad, and sandwiches.
- For food nutrition, Food-A-Pedia was used.

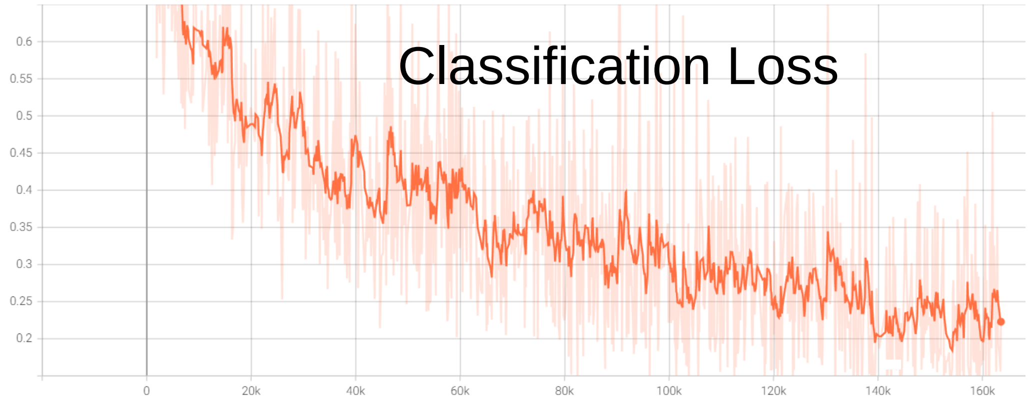
Object Detector Details

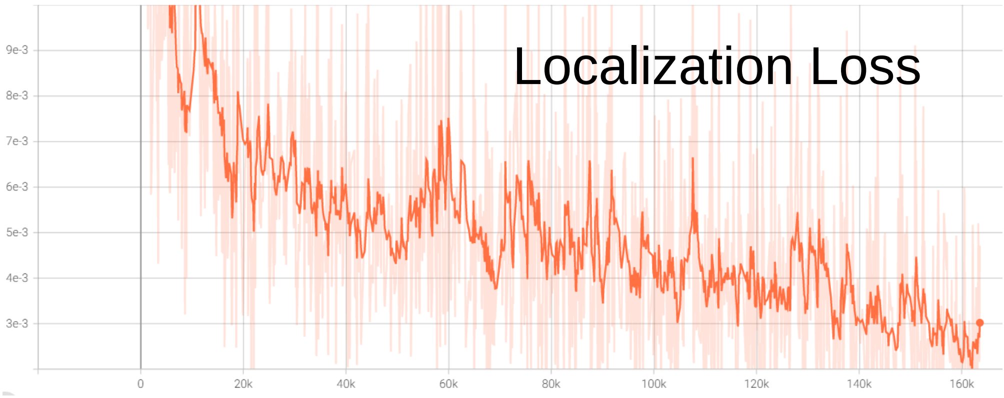
- Data Augmentation.
  - Horizontal Flip.
  - Crop with a minimum scale size of 0.1 and a maximum scale size of 2.0.
  - Padding to the maximum dimension has been kept to True.
- Transfer Learning.
- OD Model:
  - Pre-trained EfficientDet D0.
  - It is EfficientNet B0 + a bidirectional feature pyramid network (FPN).
- For Localization:
  - Single Shot MultiBox Detector (SSD)
- Loss Functions:
  - For classification, the weighted sigmoid focal loss function.
  - For localization, the weighted smooth L1 loss function.

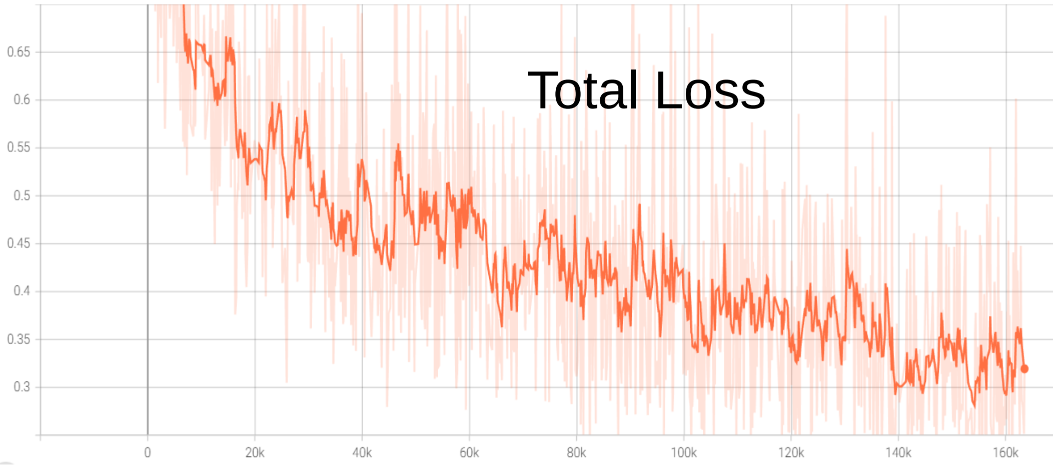
iLog 2.0: Implementation & Validation

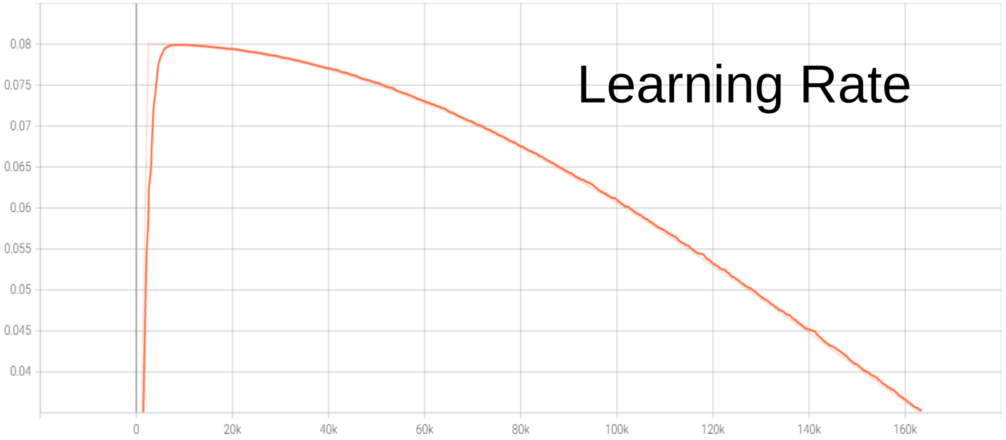
- Implemented and evaluated on a laptop with an AMD Ryzen 7 4800H with Radeon Graphics 2.90 GHz processor, 32.0 GB RAM, and a NVIDIA GeForce RTX 2060 6GB GPU.
- Raspberry Pi 4 has been used as an alternative to cloud storage for this preliminary work.
- TensorFlow 2.0 Object Detection API has been used for food detection.
- Stochastic Gradient Descent (SGD) with Momentum has been used as the optimizer with an initial learning rate of 0.08 and a learning schedule with cosine decay.
- Google Flutter for Mobile App development.

Training Curves





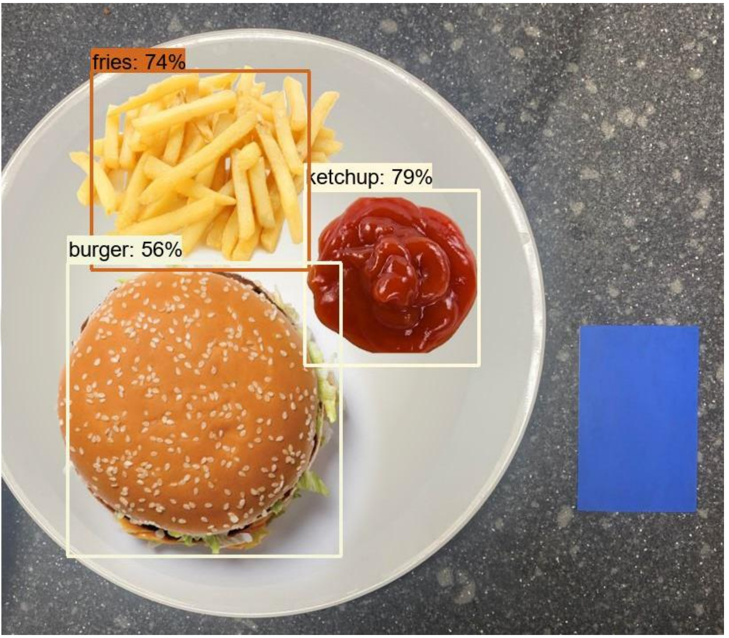




Results: Classification by iLog 2.0

- To evaluate the model, 374 images have been used.
- In almost all scenarios, food classification with localization was correct.
- However, the confidence scores in several images are moderate due to no space or very little space between two different foods on the plate.
- More versatile food plating is required to have higher a confidence score.

Nutritional Value Estimation by iLog 2.0



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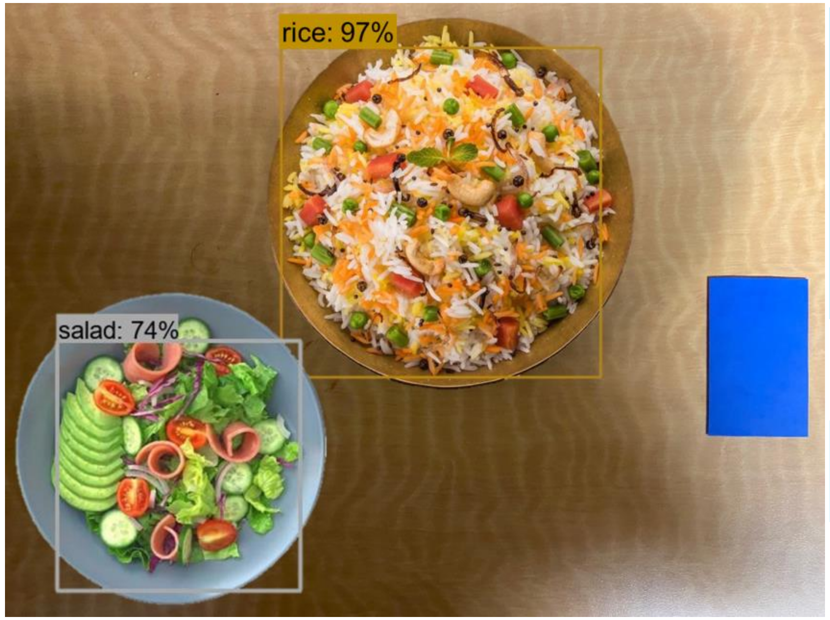


Food Item	Saturated Fat (g)	Sugar (g)	Sodium (mg)	Protein (g)	Carbohydrates (g)
Rice	0.3	0.3	6	12.9	135
Salad	0.8	3.9	264	1.1	7
Total	1.1	4.2	270	14	142

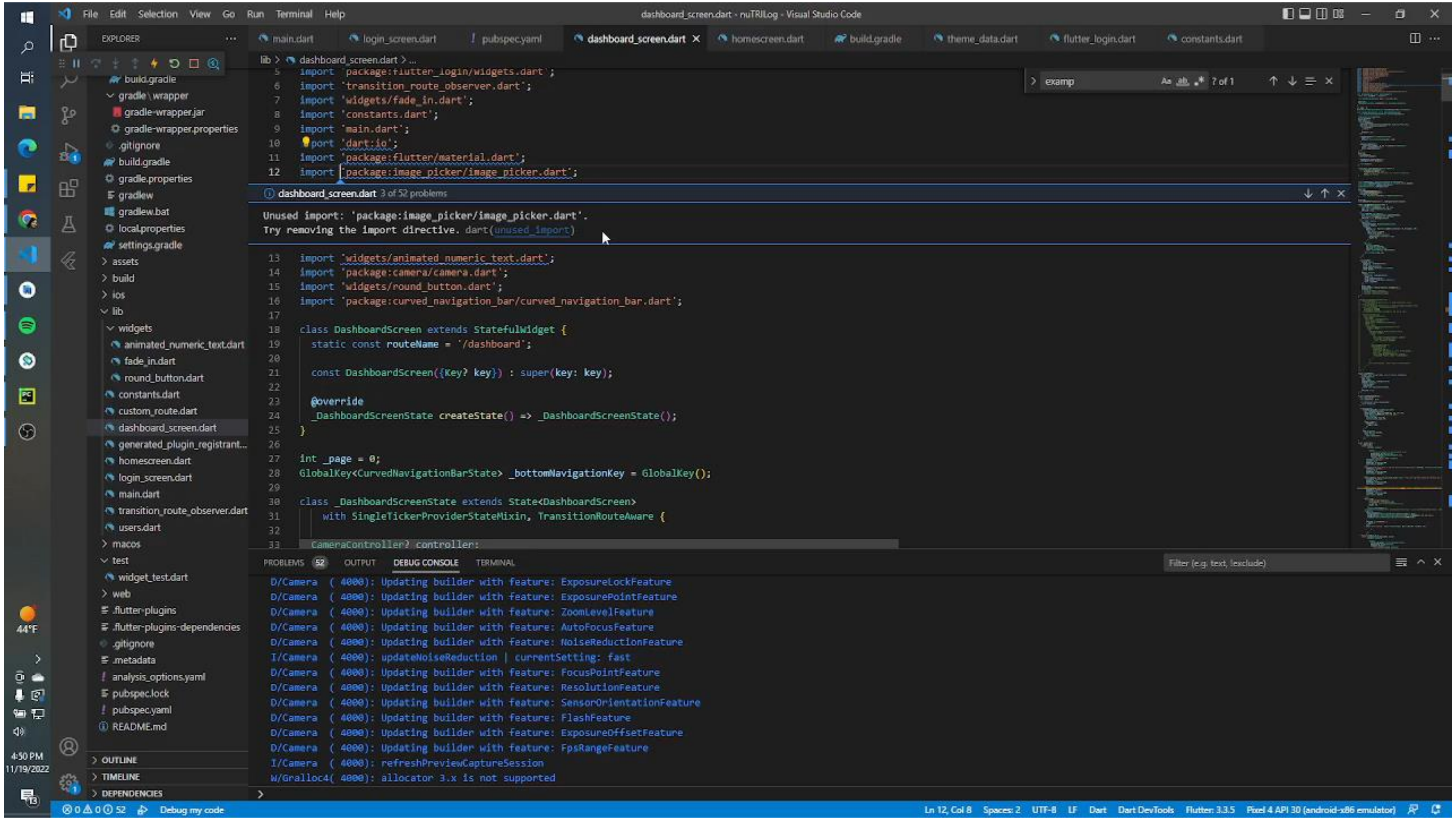
Performance Metrics of iLog 2.0

Types	Metrics	Values
Classification	Recall	90.0%
	Precision	80.3%
	IoU	73.7%
Localization	Dice Coefficient	80.3%
	IoU	68.0%

Why is recall much higher than precision?

As it is more important for the model to correctly identify that a certain food is present (lowering false negatives), even if this means identifying more food than there is (increasing false positives), the user should not be given a nutritional estimate that is possibly lower than what they are eating because this can jeopardize their health.

iLog 2.0: Demo


File Edit Selection View Go Run Terminal Help
dashboard_screen.dart - nuTRILog - Visual Studio Code
EXPLORER
main.dart
login_screen.dart
pubspec.yaml
dashboard_screen.dart
homescreen.dart
build.gradle
theme_data.dart
flutter_login.dart
constants.dart
import 'transition_route_observer.dart';
import 'widgets/fade_in.dart';
import 'constants.dart';
import 'main.dart';
import 'dart:io';
import 'package:flutter/material.dart';
import 'package:image_picker/image_picker.dart';
dashboard_screen.dart 3 of 52 problems
Unused import: 'package:image_picker/image_picker.dart'.
Try removing the import directive. dart(unused_import)
import 'widgets/animated_numeric_text.dart';
import 'package:camera/camera.dart';
import 'widgets/round_button.dart';
import 'package:curved_navigation_bar/curved_navigation_bar.dart';
class DashboardScreen extends StatefulWidget {
static const routeName = '/dashboard';
const DashboardScreen({Key? key}) : super(key: key);
@override
_DashboardScreenState createState() => _DashboardScreenState();
}
int _page = 0;
GlobalKey<CurvedNavigationBarState> _bottomNavigationKey = GlobalKey();
class _DashboardScreenState extends State<DashboardScreen>
with SingleTickerProviderStateMixin, TransitionRouteAware {
CameraController? controller;
PROBLEMS 52
OUTPUT
DEBUG CONSOLE
TERMINAL
D/Camera (4000): Updating builder with feature: ExposureLockFeature
D/Camera (4000): Updating builder with feature: ExposurePointFeature
D/Camera (4000): Updating builder with feature: ZoomLevelFeature
D/Camera (4000): Updating builder with feature: AutoFocusFeature
D/Camera (4000): Updating builder with feature: NoiseReductionFeature
I/Camera (4000): updateNoiseReduction | currentSetting: fast
D/Camera (4000): Updating builder with feature: FocusPointFeature
D/Camera (4000): Updating builder with feature: ResolutionFeature
D/Camera (4000): Updating builder with feature: SensorOrientationFeature
D/Camera (4000): Updating builder with feature: FlashFeature
D/Camera (4000): Updating builder with feature: ExposureOffsetFeature
D/Camera (4000): Updating builder with feature: FpsRangeFeature
I/Camera (4000): refreshPreviewCaptureSession
W/Gralloc4(4000): allocator 3.x is not supported
Debug my code
Ln 12, Col 8 Spaces: 2 UTF-8 LF Dart Dart DevTools Flutter: 3.3.5 Pixel 4 API 30 (android-x86 emulator)
4:50 PM
11/19/2022

Conclusions & Future Work

- It is an automatic system. It can measure the food's nutritional values from the image of the food.
- It is precise as food quantification is done from the exact volume of the food.
- However, no provision is made for unfinished meals. If the user does not finish the meal, the accurate measurement will not be reflected in the system.
- In future, a no-reference food quantification system will be proposed.
- The precision and IoU need to be improved.
- More food items will be included in the system. The system will be updated cuisine by cuisine.

Thank You!!