Advancing Food Volume and Weight Measurement: Integrative Approaches for Precision Portion Estimation

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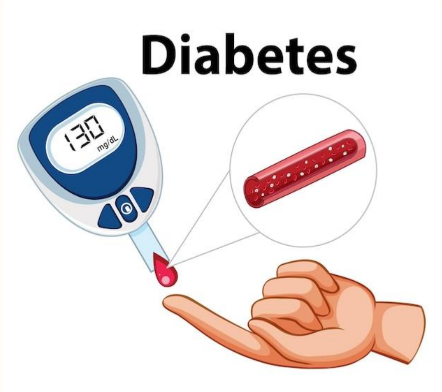
報告日期:114/01/06

Table of contents

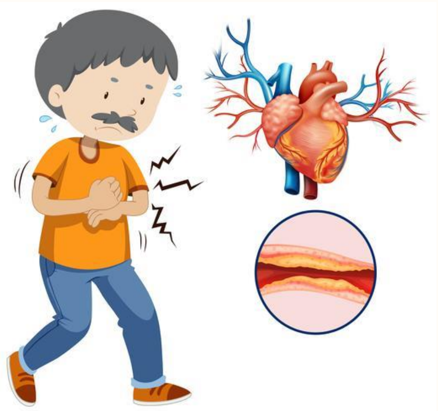
Introduction

Dietary Intake and Chronic Diseases

- A **daily healthy diet** and intake of essential nutrients can significantly affect the modern lifestyle.



2021: 6.7 million→
2023: 537 million
2045: 783 million



Each year: 17.9 million →
(32% of all deaths)

2020: 39 million
(under the age of five)

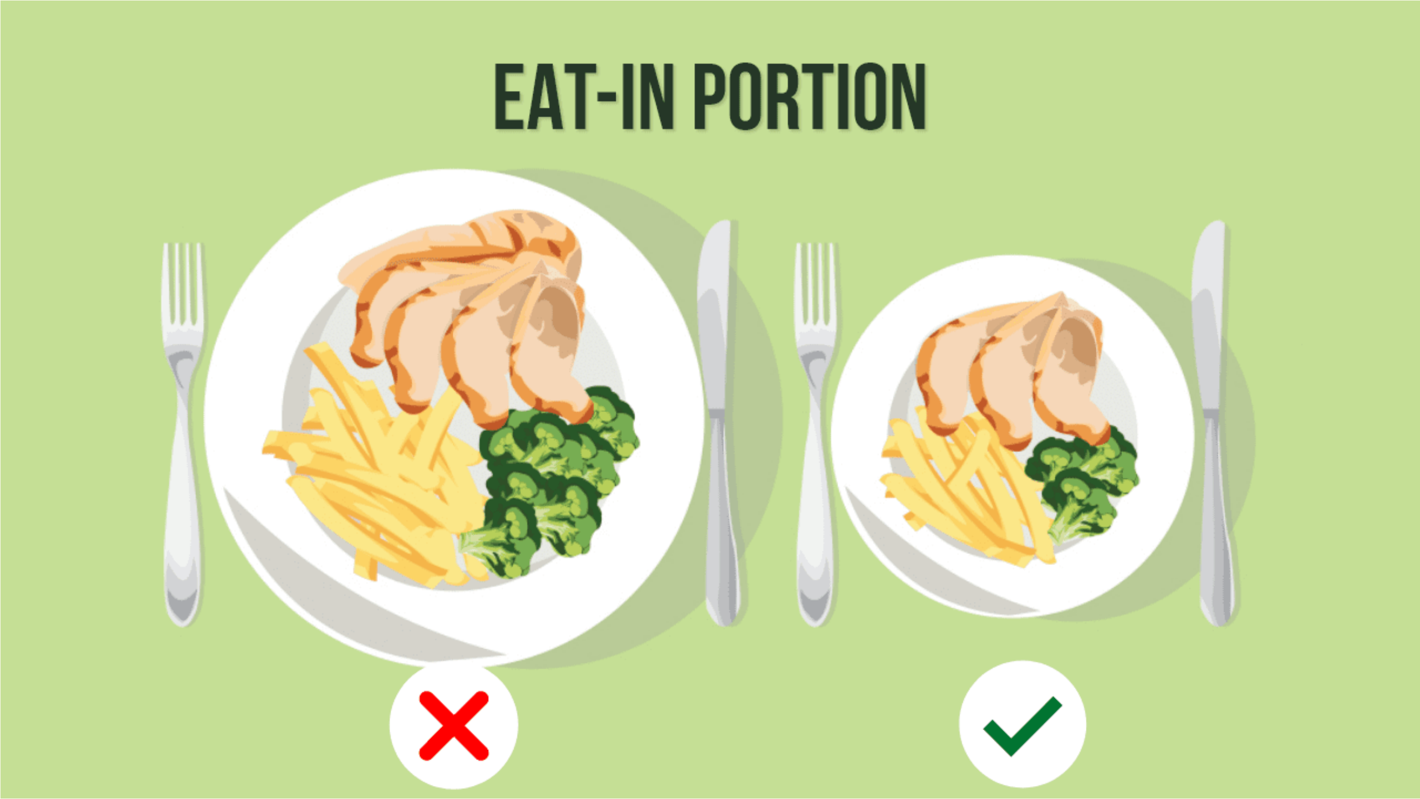
T. P. Velavan and C. G. Meyer.(2020)

C. Koliaki, S. Liatis, and A. Kokkinos.(2022)

Diet Intake and Disease Management

- **Dietary portion management** is one of the key to preventing and managing diabetes, cardiovascular diseases, and obesity.
- Maintaining an **appropriate dietary intake** supports and improves metabolic health, aids in weight control, and helps prevent chronic diseases.

Manuela Neuenschwander, Aurélie Ballon , Katharina S Weber et al.(2019)



Diet Management and Dietary Assessment

- With AI, the Internet of Things (IoT) and computer vision are allowed to use food applications to **monitor and record their daily diet**.

- Important parts in dietary assessment system.

1 **Food Image and Nutrition Databases**
Food Classes, Images, Type of Cuisine, Image Quality, Source

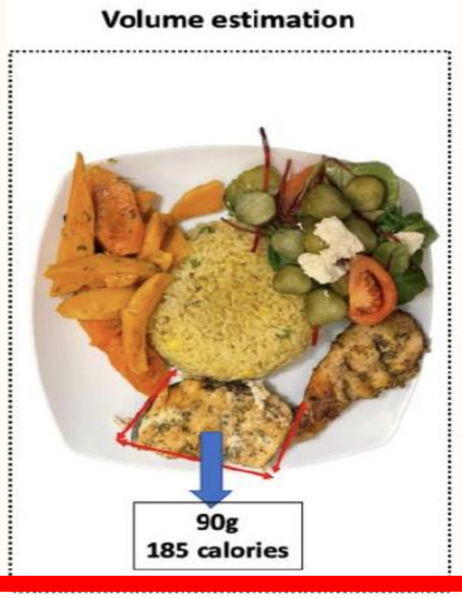
Y. Matsuda, H. Hoashi, and K. Yanai.(2012)

2 **Food Classification Systems**
Traditional Machine Learning, Deep Learning

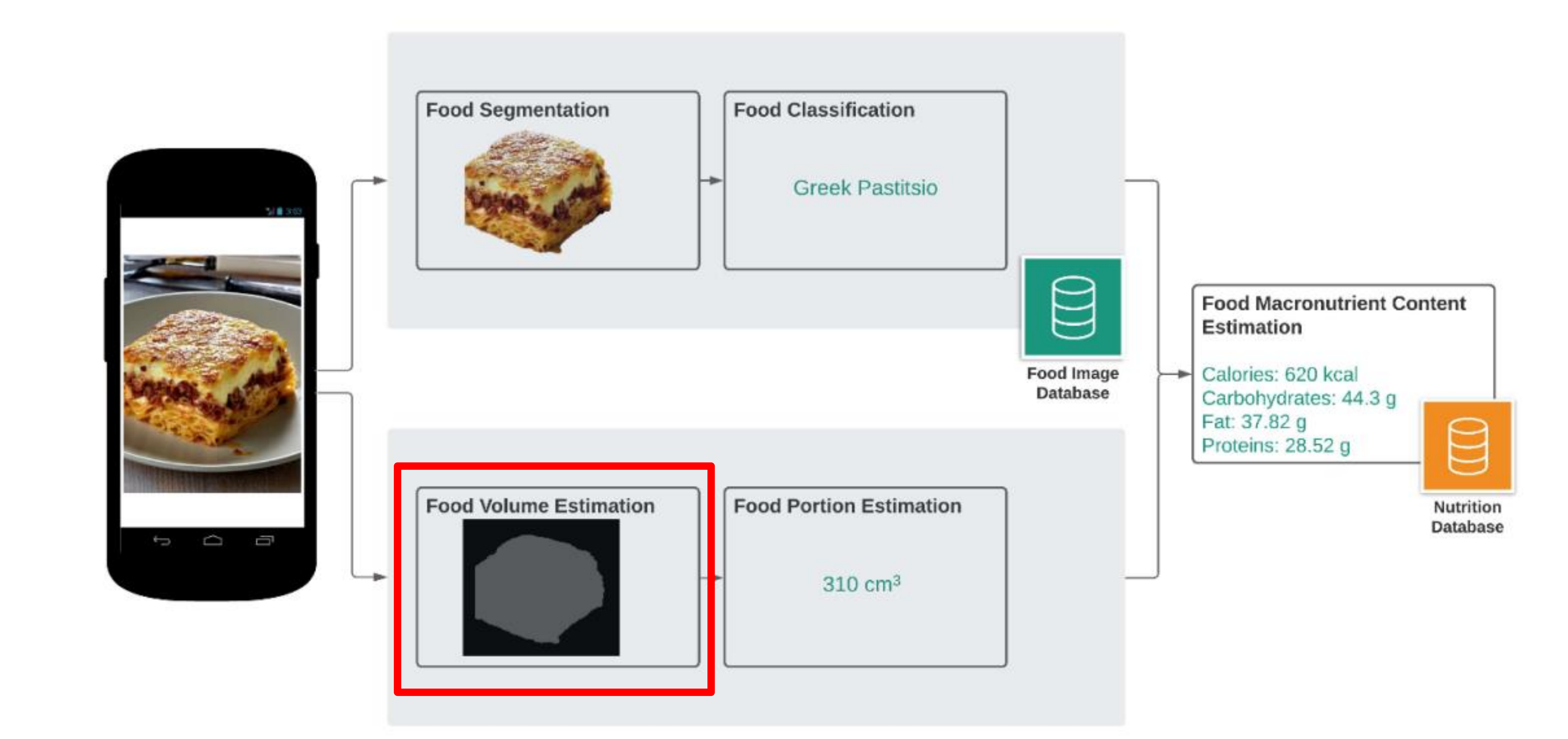
L. Xiao, T. Lan, D. Xu, W. Gao, and C. Li.(2021)

3 **Food Volume and Weight Estimation Systems**
Stereo-based Approaches, Depth Camera, Pre-build shape templates, Perspective Transformation, Deep learning

P. Pouladzadeh, S. Shirmohammadi, and R. Al-Maghrabi.(2014)

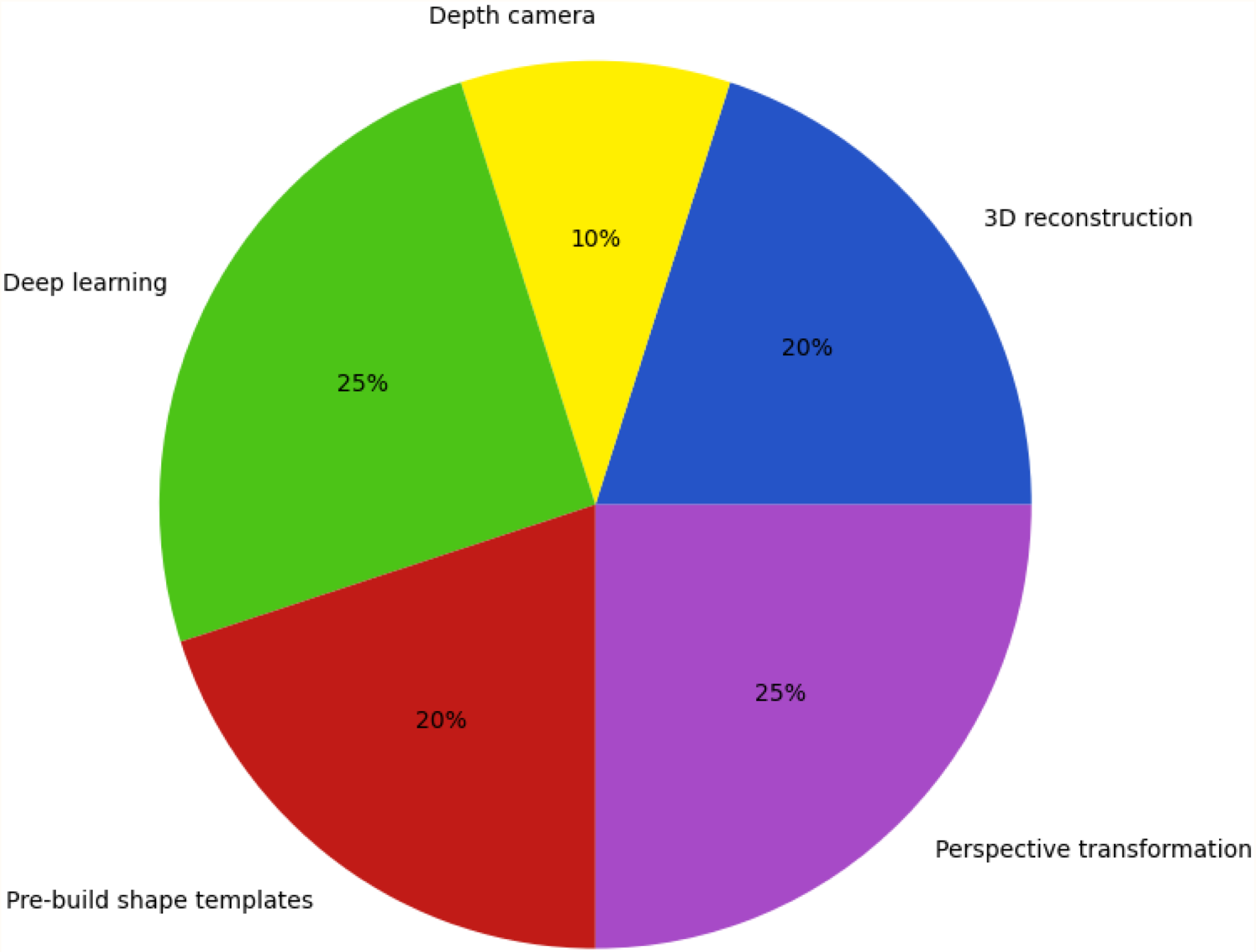


Vision-based Dietary Assessment System



Fotios S. Konstantakopoulos, Eleni I. Georga, I. Fotiadis et al.(2024)

Percentage of Portion Estimation Approaches



Fotios S. Konstantakopoulos, Eleni I. Georga, I. Fotiadis et al.(2024)

Motivation

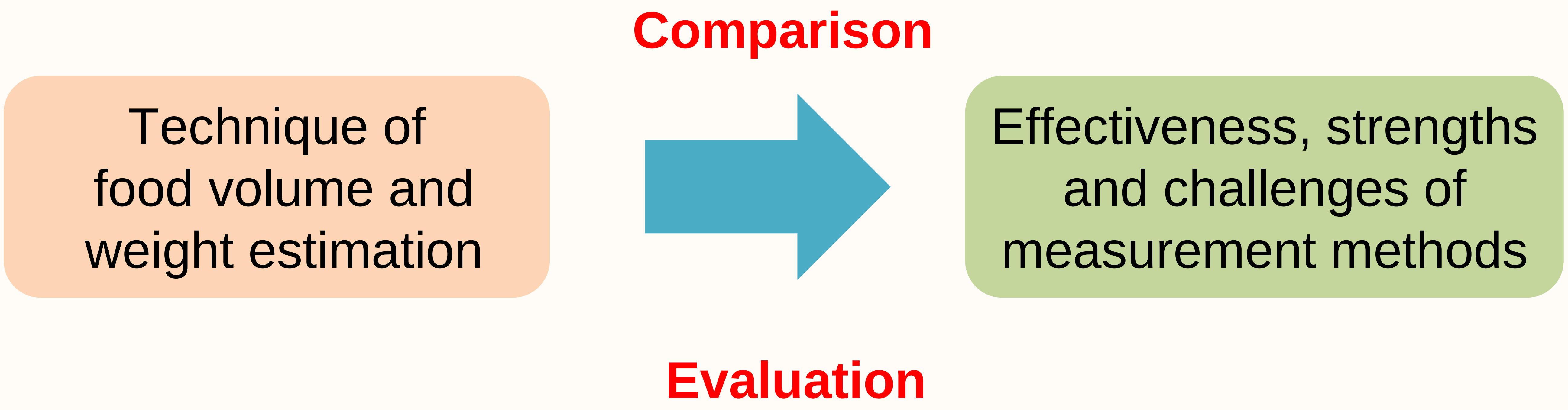
- The increasing prevalence of chronic diseases necessitates more **accurate** and accessible tools for **diet monitoring**.
- Current methods often lack **precision** or require specialized equipment that may not be accessible to the general population.

Fotios S. Konstantakopoulos, Eleni I. Georga, I. Fotiadis et al.(2024)

- There is potential to develop systems that are both **accurate** and **user-friendly**, making it easier for individuals to **manage their daily diet effectively**.

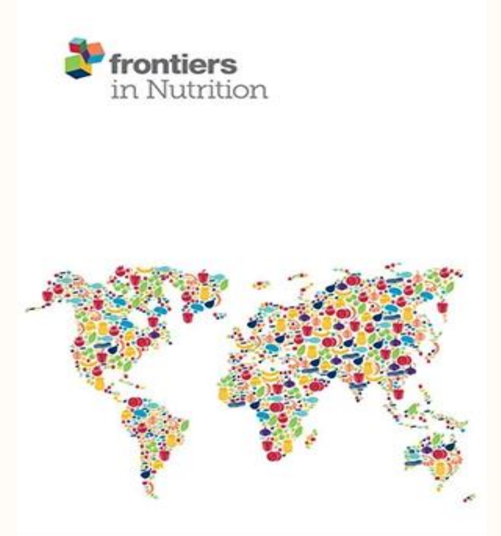
AIM

- To **compare** and **evaluate** three innovative systems designed for food volume and weight estimation.



Paper Chosen

Paper Chosen

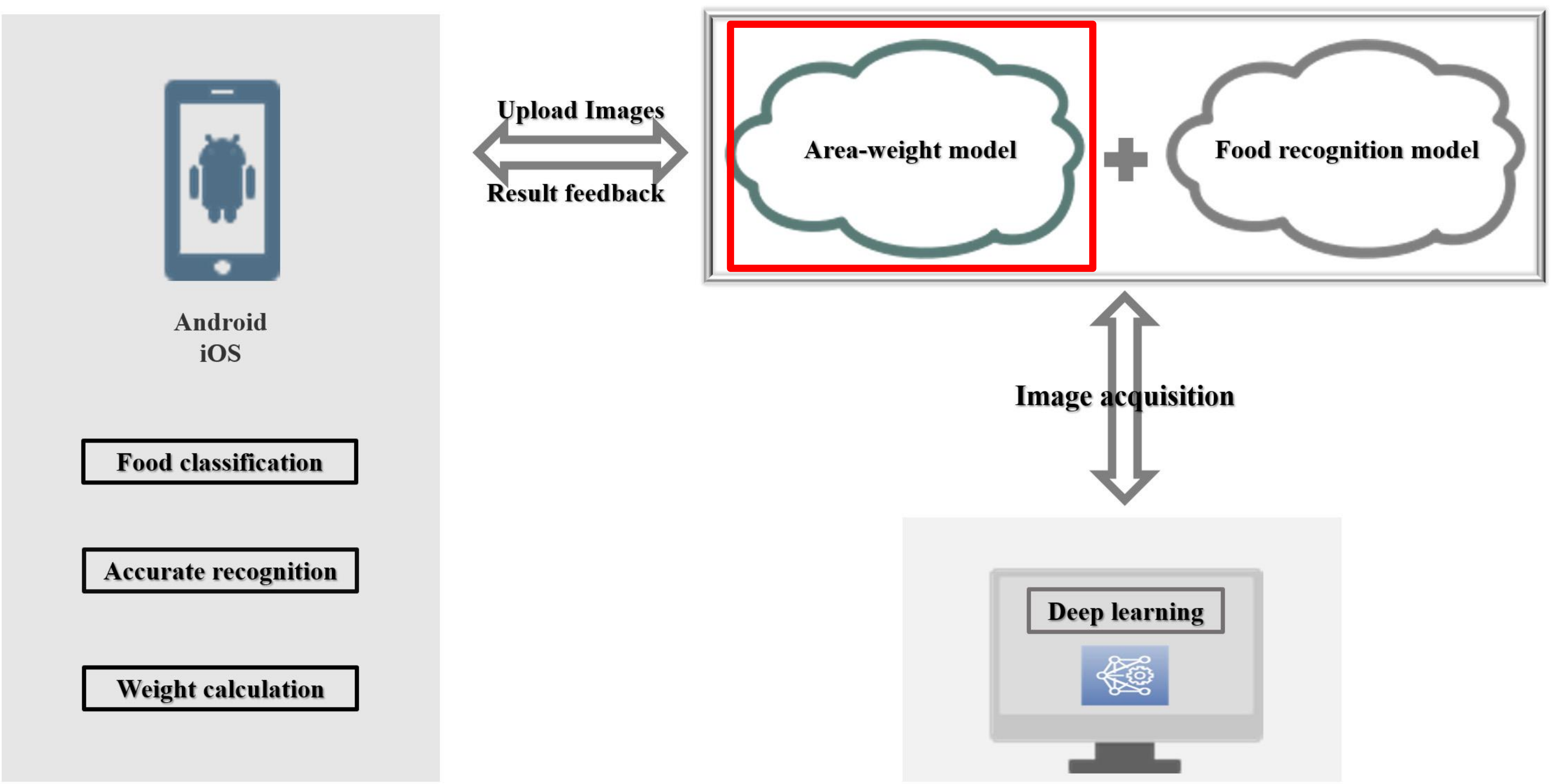
Title	Authors	IF/Rank	Country	Journal
Paper 1 Eliminate the hardware: Mobile terminals-oriented food recognition and weight estimation system	Qinqiu Zhang et al(2022)	6.58/Q1		
Paper 2 Food Volume Estimation by Integrating 3D Image Projection and Manual Wire Mesh Transformations	Shamus P. Smith et al(2022)	5.8/Q1		
Paper 3 FVEstimator: A novel food volume estimator Wellness model for calorie measurement and healthy living	Prachi Kadam et al(2022)	5.2/Q1		

Methods

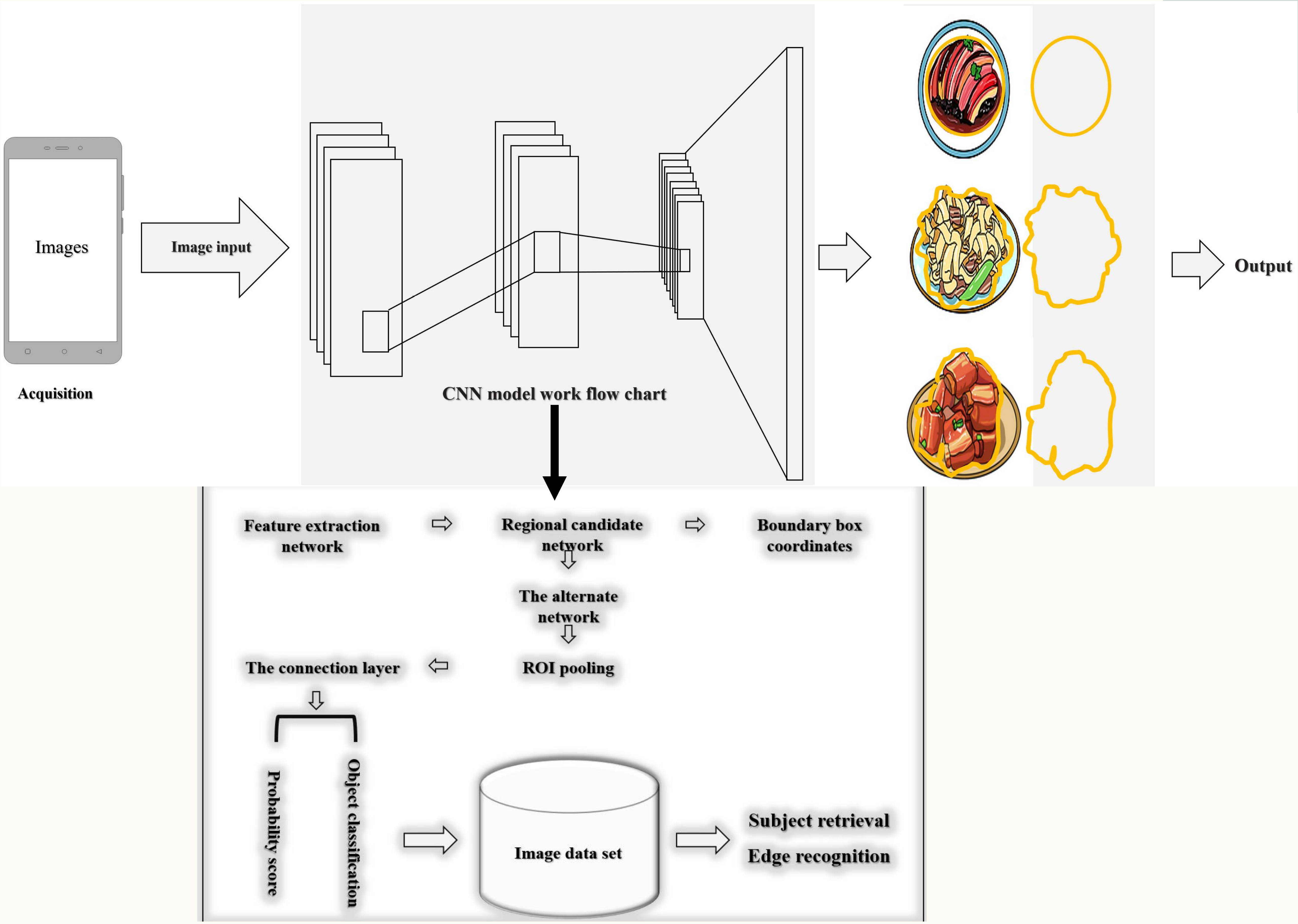
Overview of Methods

Title	Data Source of Images	Technique	Model
Paper 1 Eliminate the hardware: Mobile terminals-oriented food recognition and weight estimation system	• Aliyun Cloud	• Convex lens imaging principle	• Convolutional Neural Network (CNN)
Paper 2 Food Volume Estimation by Integrating 3D Image Projection and Manual Wire Mesh Transformations	• VISIDA	• 3D Image Projection • Manual Wire Mesh • Reference Objects	• Machine Learning
Paper 3 FVEstimator: A novel food volume estimator Wellness model for calorie measurementand healthy living	• Established by the authors • Crowdsourcing	• Pixel Per Metric Method • Reference Objects • Hemispherical Equation	• Mask-based R-CNN • ResNet model

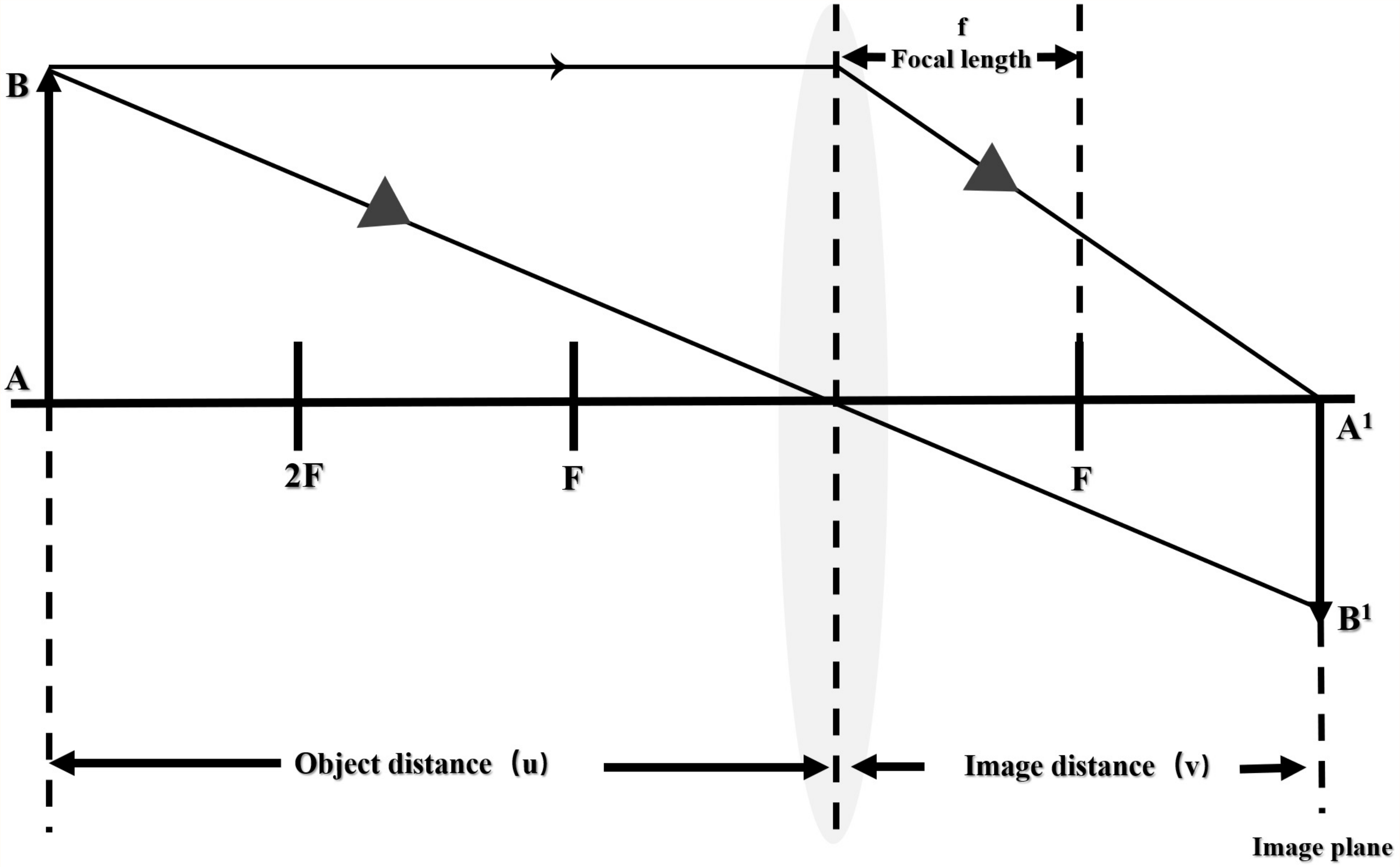
Paper 1: Simplified Overview

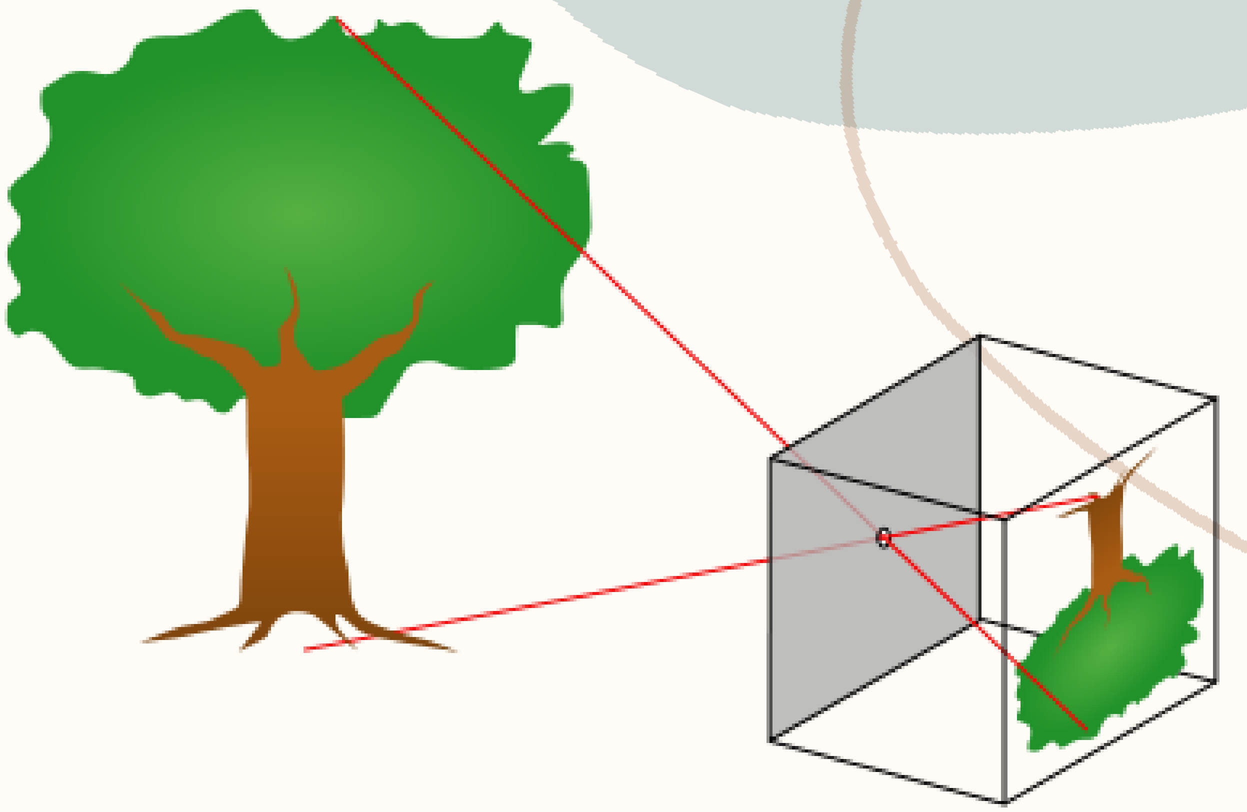


Paper 1: Food Calculation Model (CNN)



Paper 1: Area Measurement

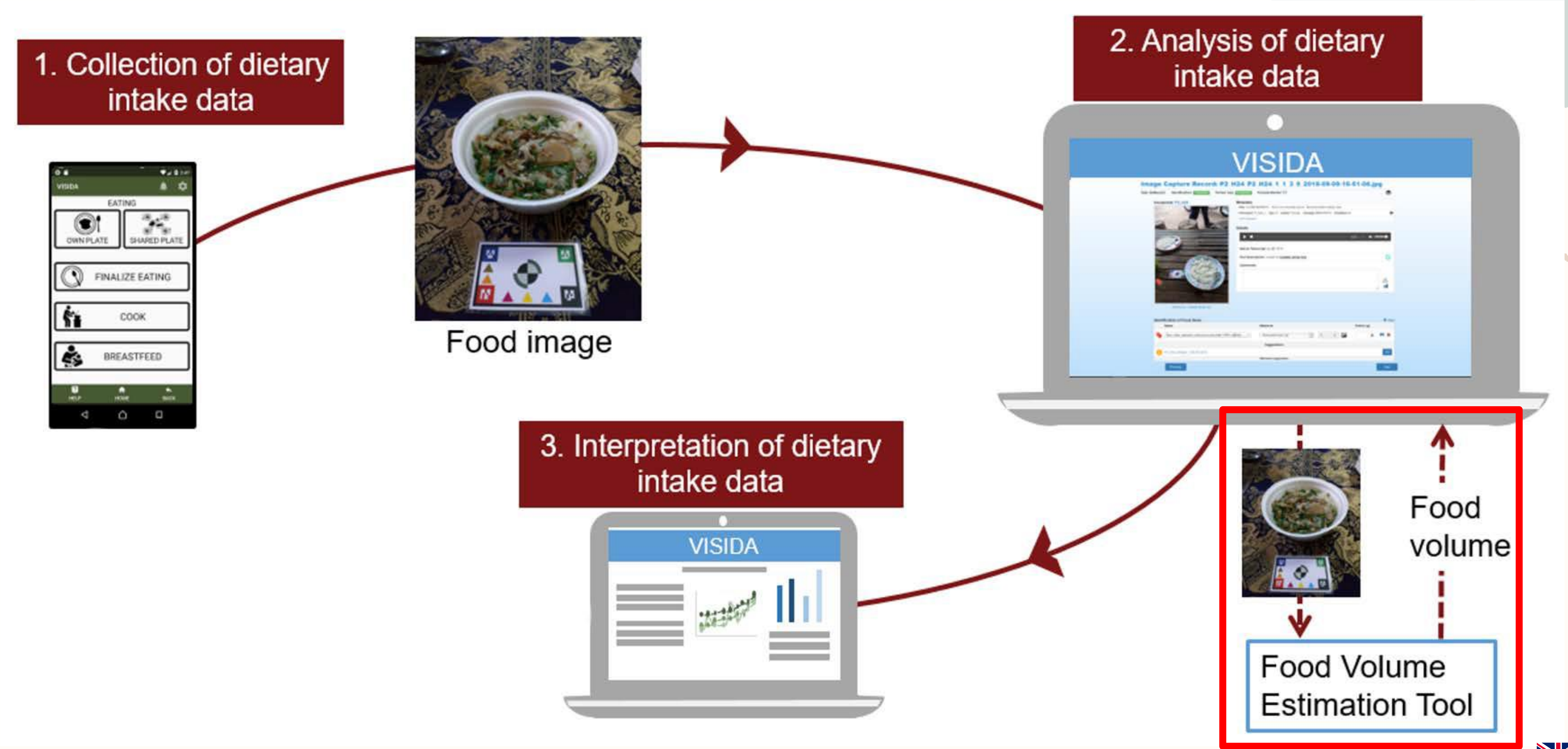




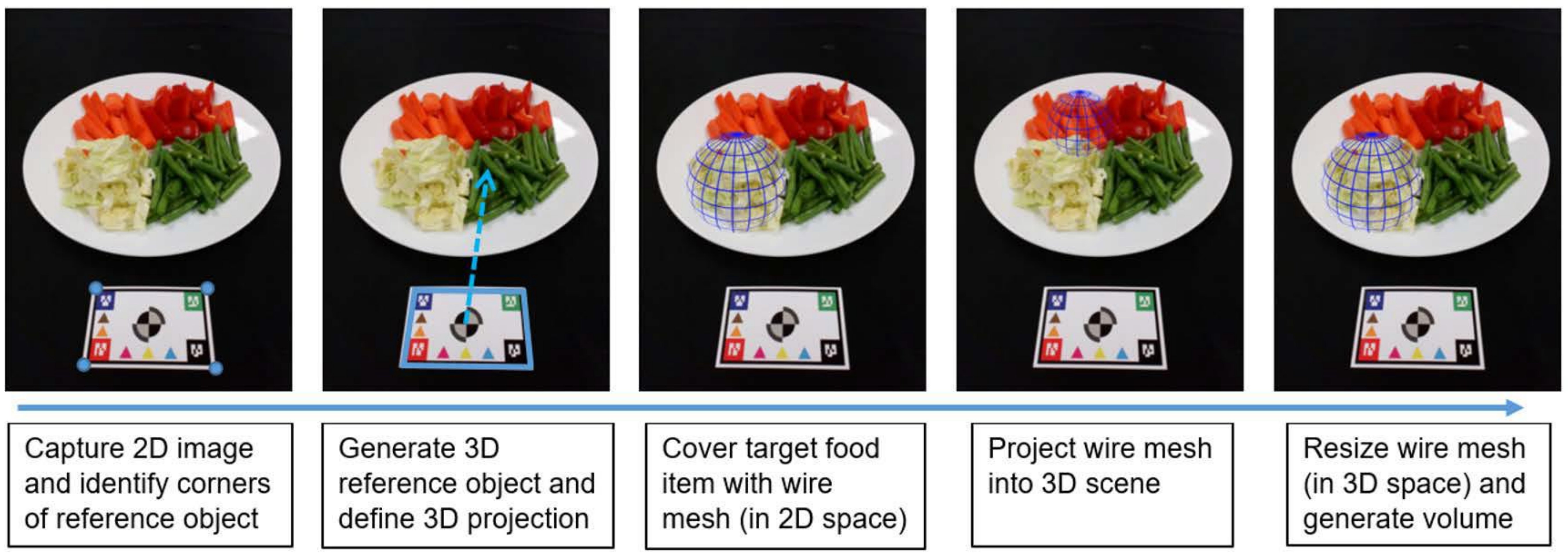
物距 u、像距 v 和焦距 f

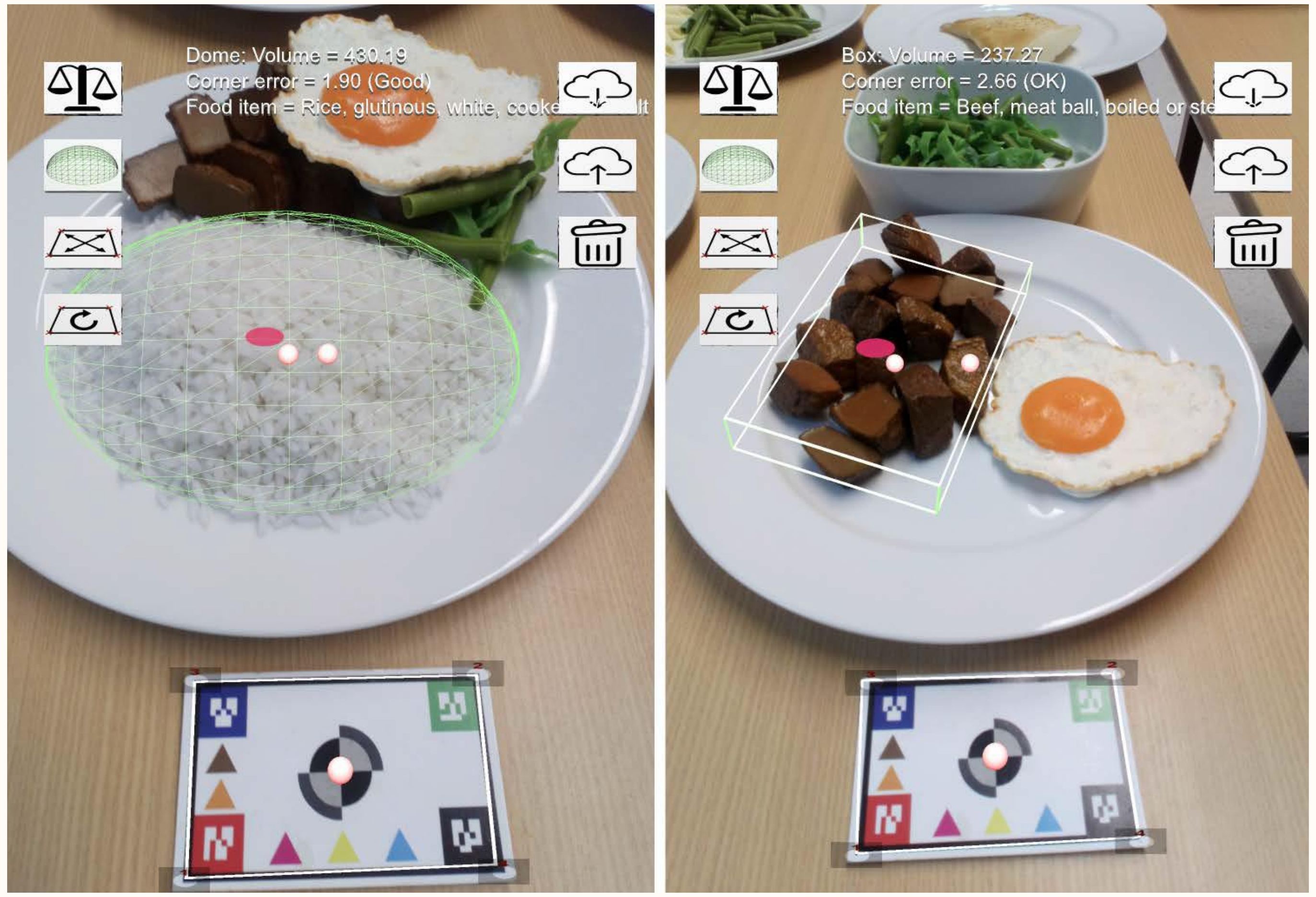
$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

Paper 2: Simplified Overview



Paper 2: Food Volume Estimation (3D Image Projection)

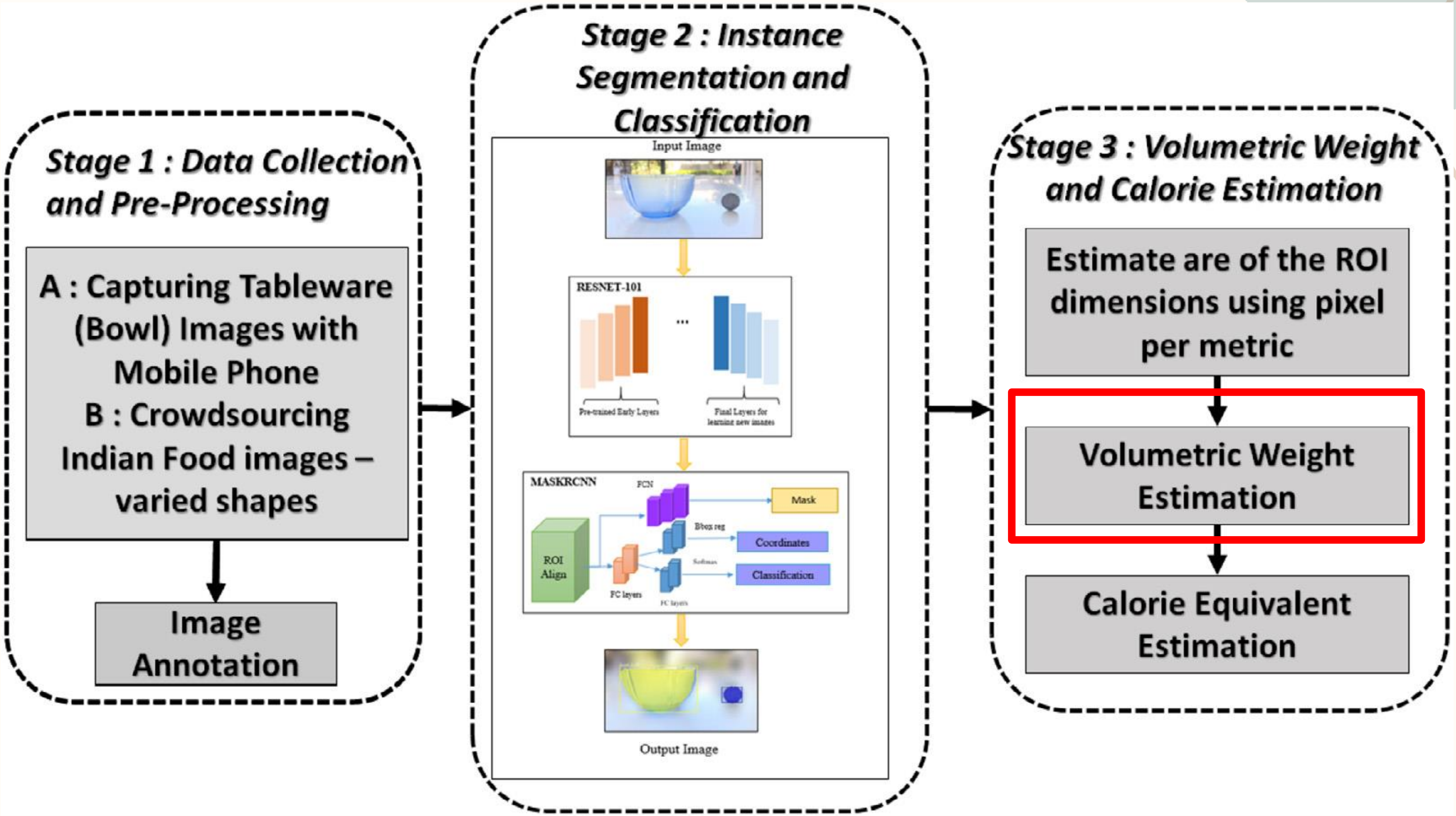




Paper 2: Food Volume Estimation (3D Image Projection)

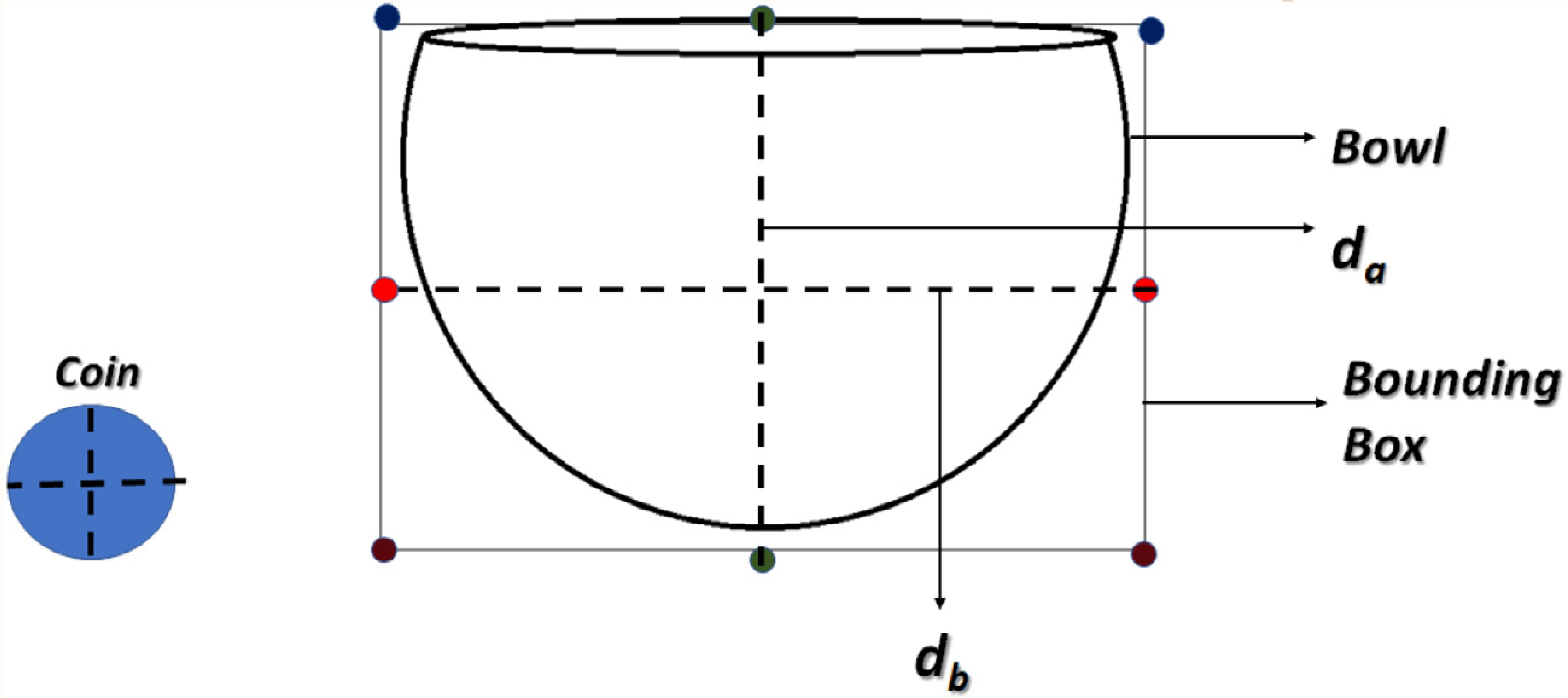
SPHERE 1 (221) BOWL 1 (67) DOME 1 (26) MED BOX 1 (700) LRG BOX 1 (920)

Paper 3: Simplified overview (Mask-RCNN)



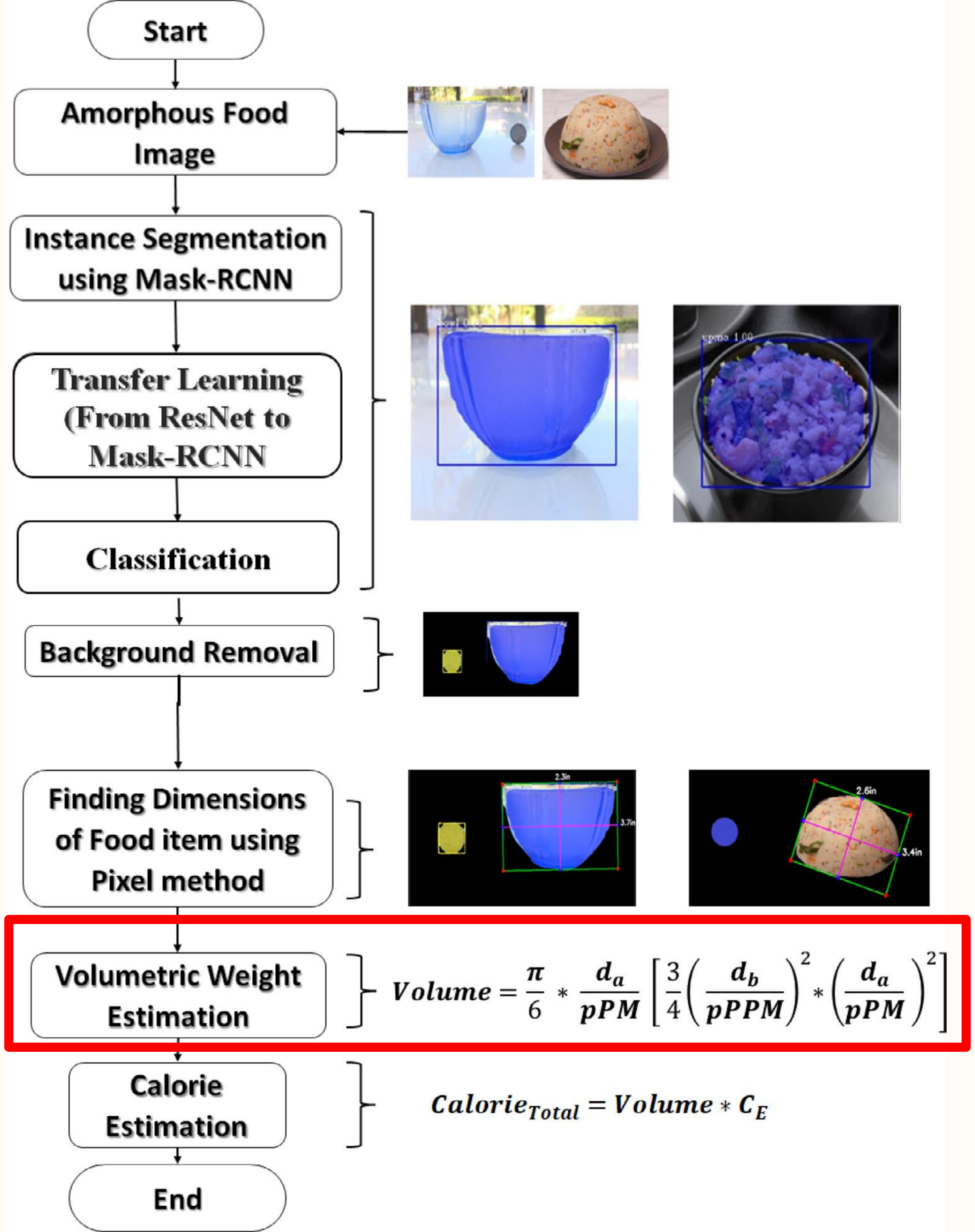
Paper 3: Food Volume Estimation

(Reference Objects)



Paper 3:

Food Volume estimation



Results

Result-Paper1

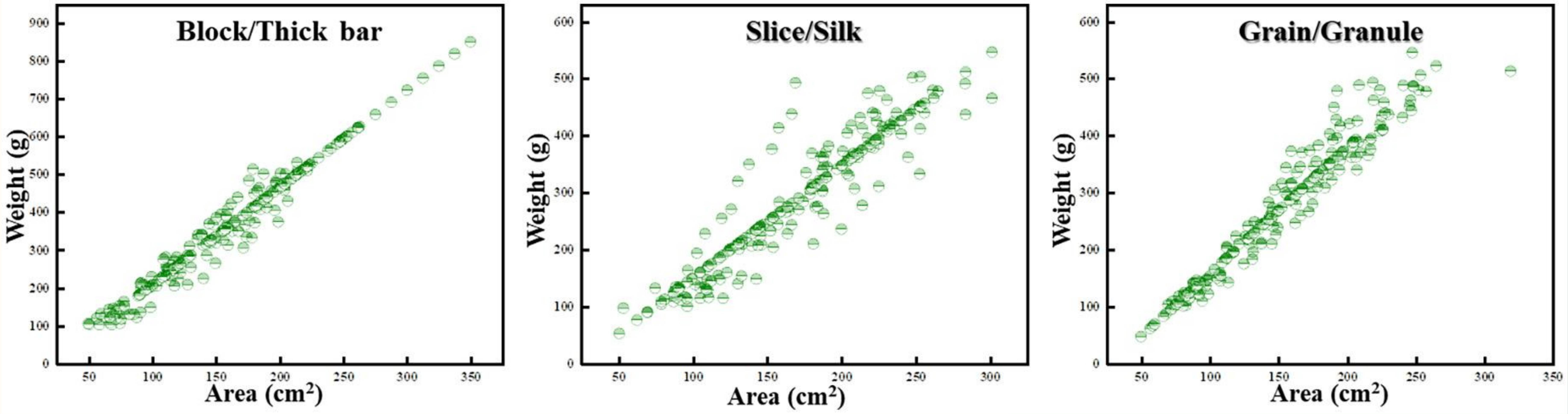
Food image area-actual food weight relationship model.

Character	Sample size	Pearson correlation	R^2	Linear correlation formula
Block/Thick bar	204	0.986**	0.971**	$y = 2.5757x - 49.03$
Slice/Silk	204	0.937**	0.878**	$y = 1.9684x - 46.3$
Grain/Granule	204	0.972**	0.944**	$y = 2.2069x - 62.13$

$^{*}p < 0.05$, $^{**}p < 0.01$.

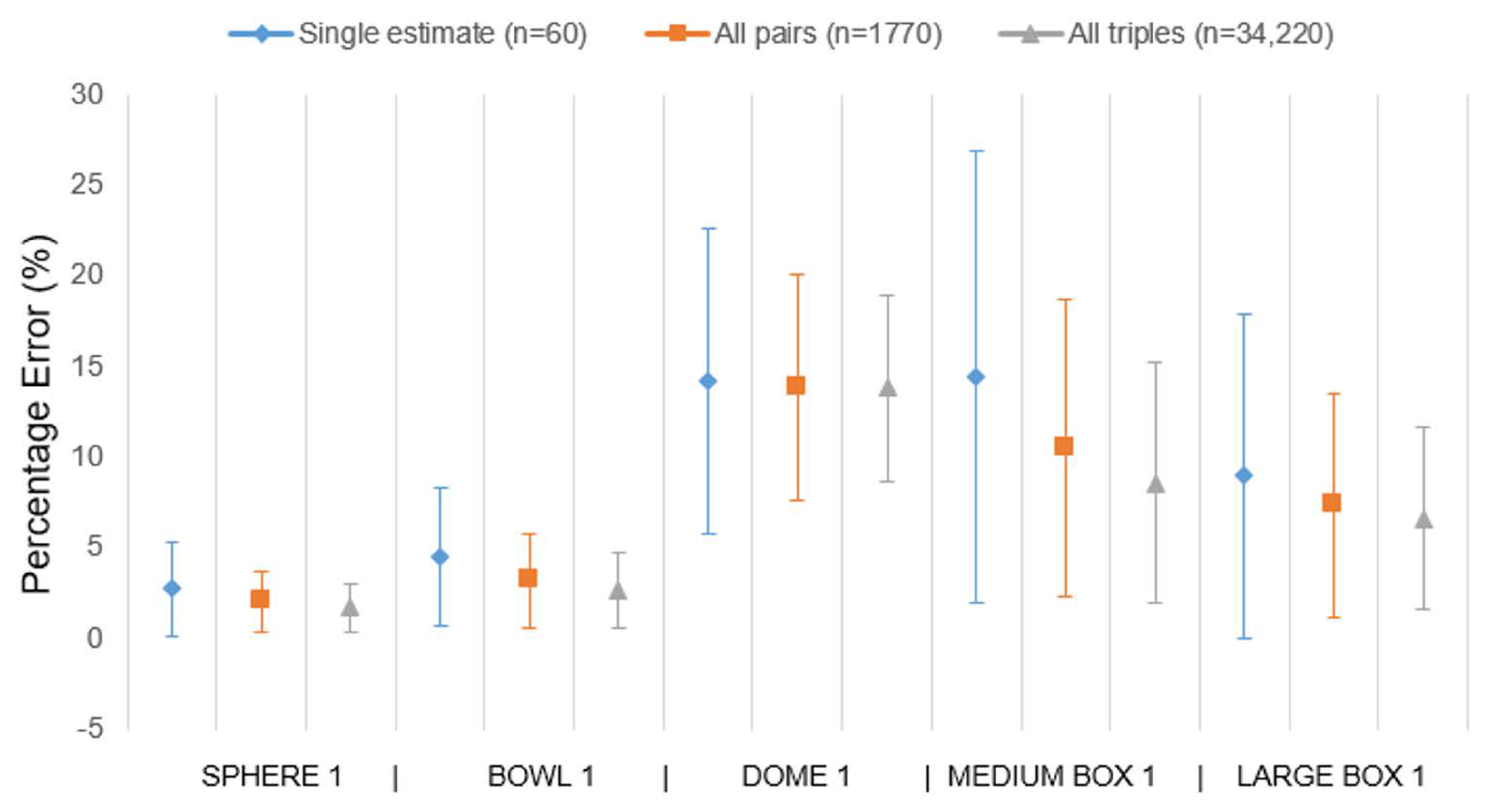
Result-Paper1

Scatter plot of food image area-actual food weight relationship.



Result-Paper2

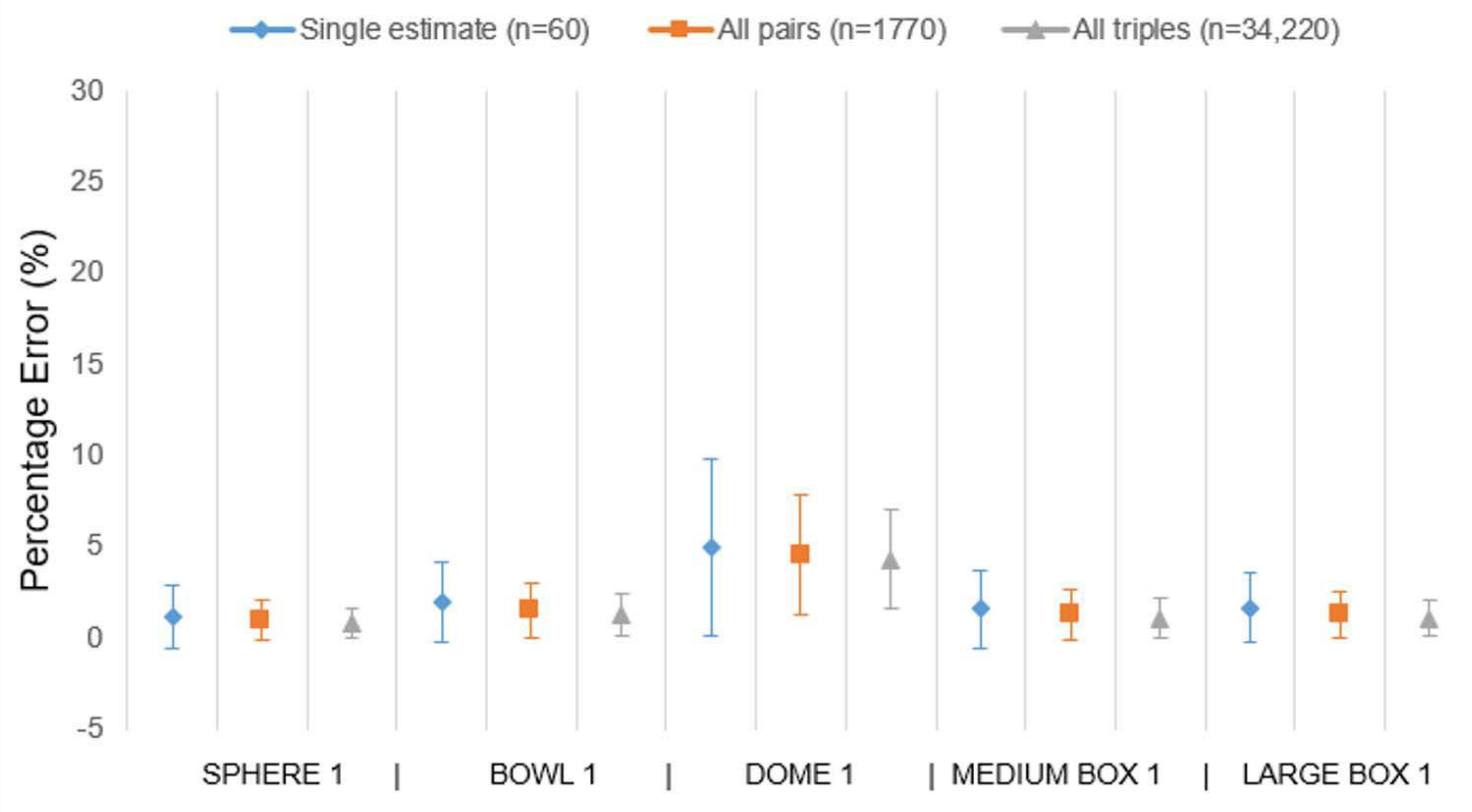
Results of the first estimate with the training images with single, pair and triple estimate combinations. (Absolute Percentage Deviation)



$$\mathrm{APD} = \frac{|\text{Actual Value} - \text{Predicted Value}|}{\text{Actual Value}} \times 100\%$$

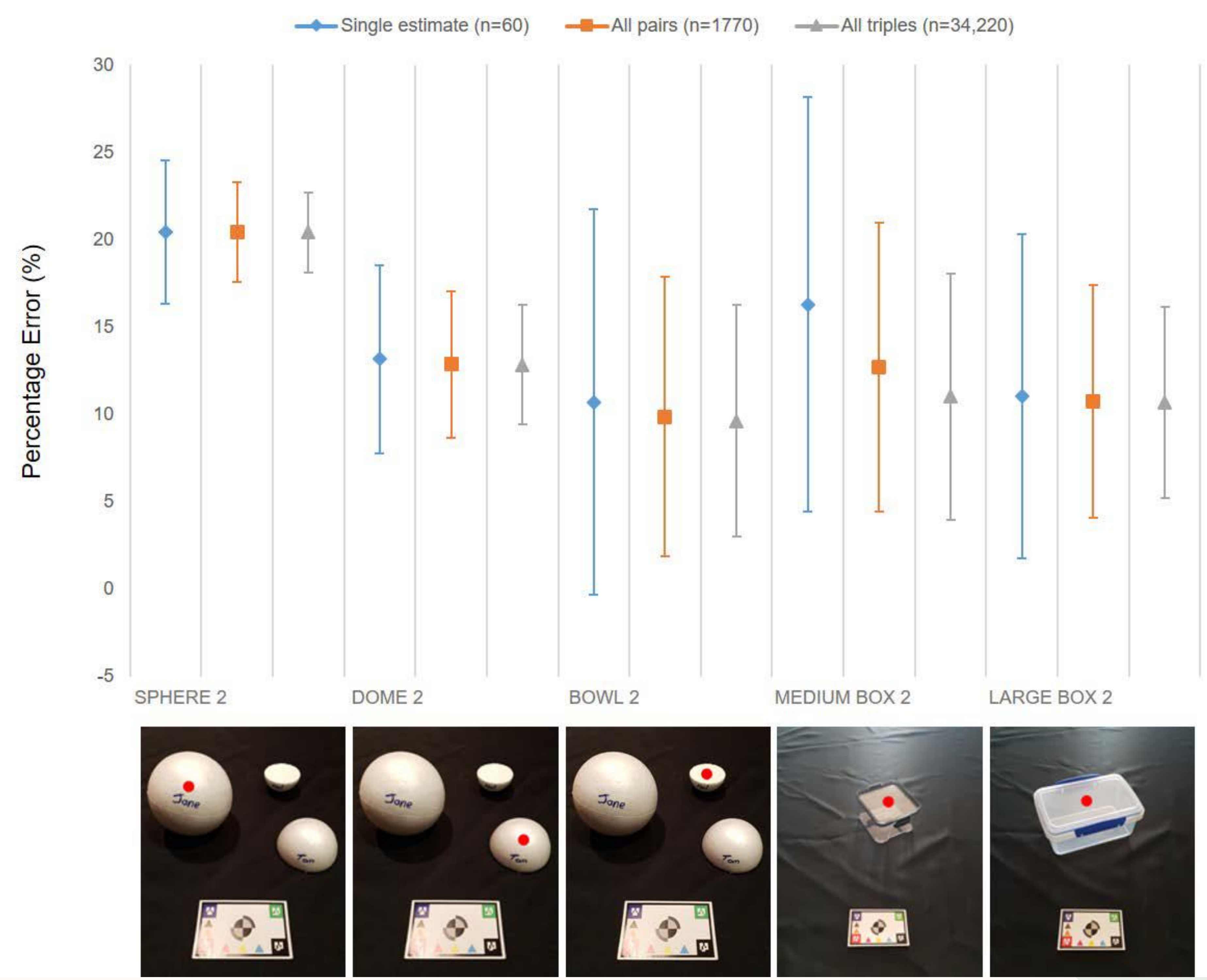
Result-Paper2

Results of the second estimate, after volume feedback, with the training images with single, pair and triple estimate combinations.



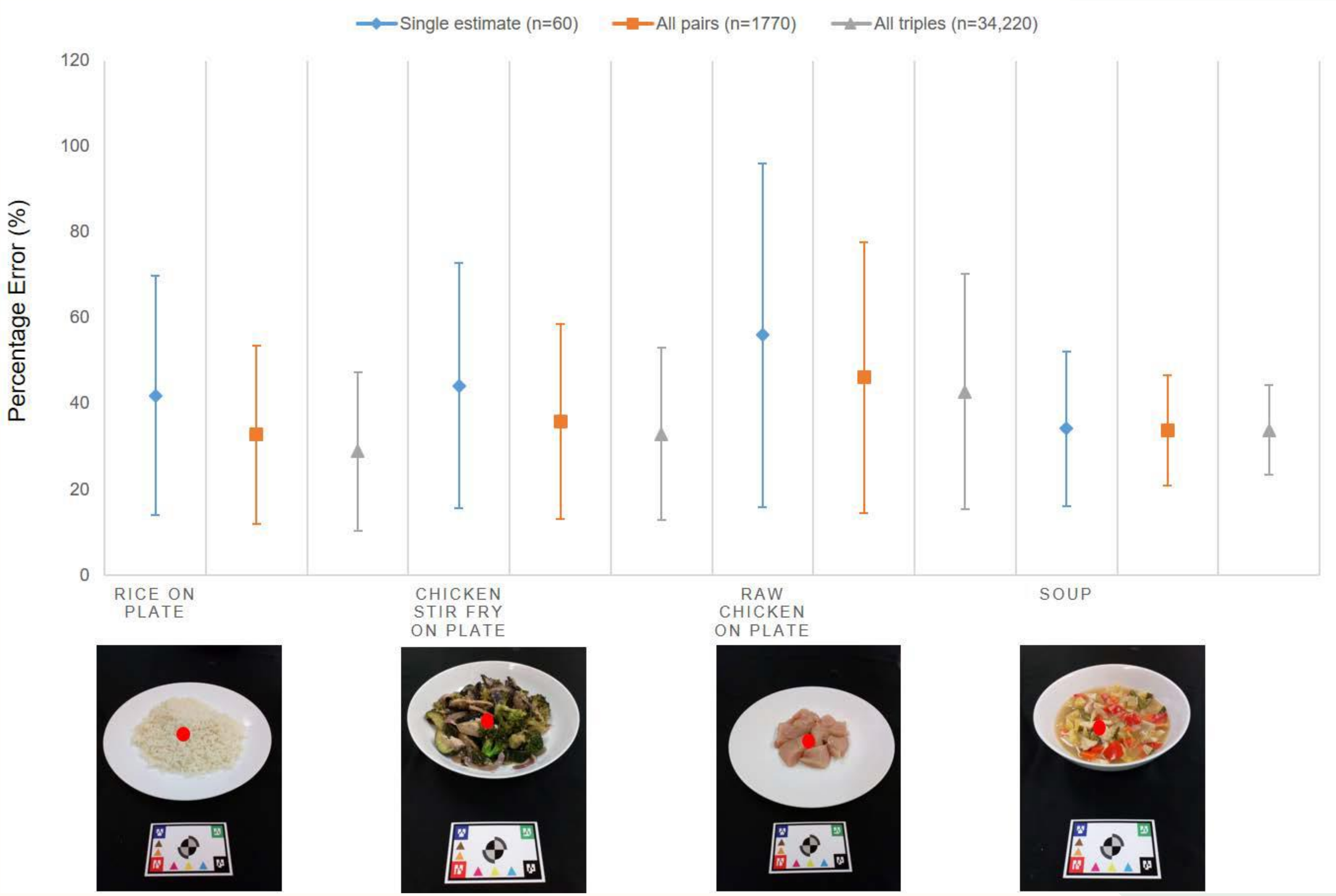
Result-Paper2

Results of the testing trials for non-food objects over mean absolute percentage deviation and percentage error.



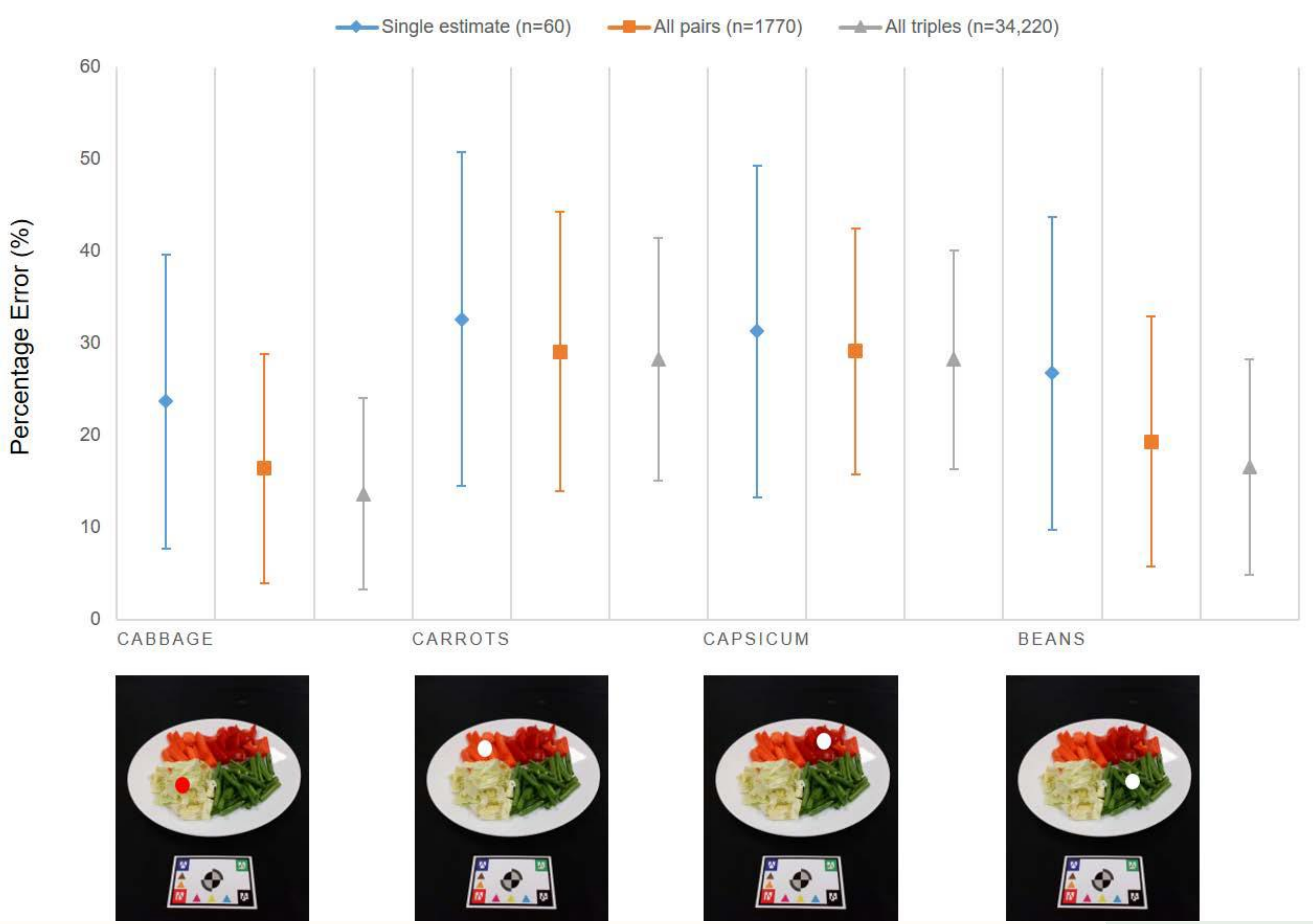
Result-Paper2

Results of the testing trials for single food items over mean absolute percentage deviation and percentage error.



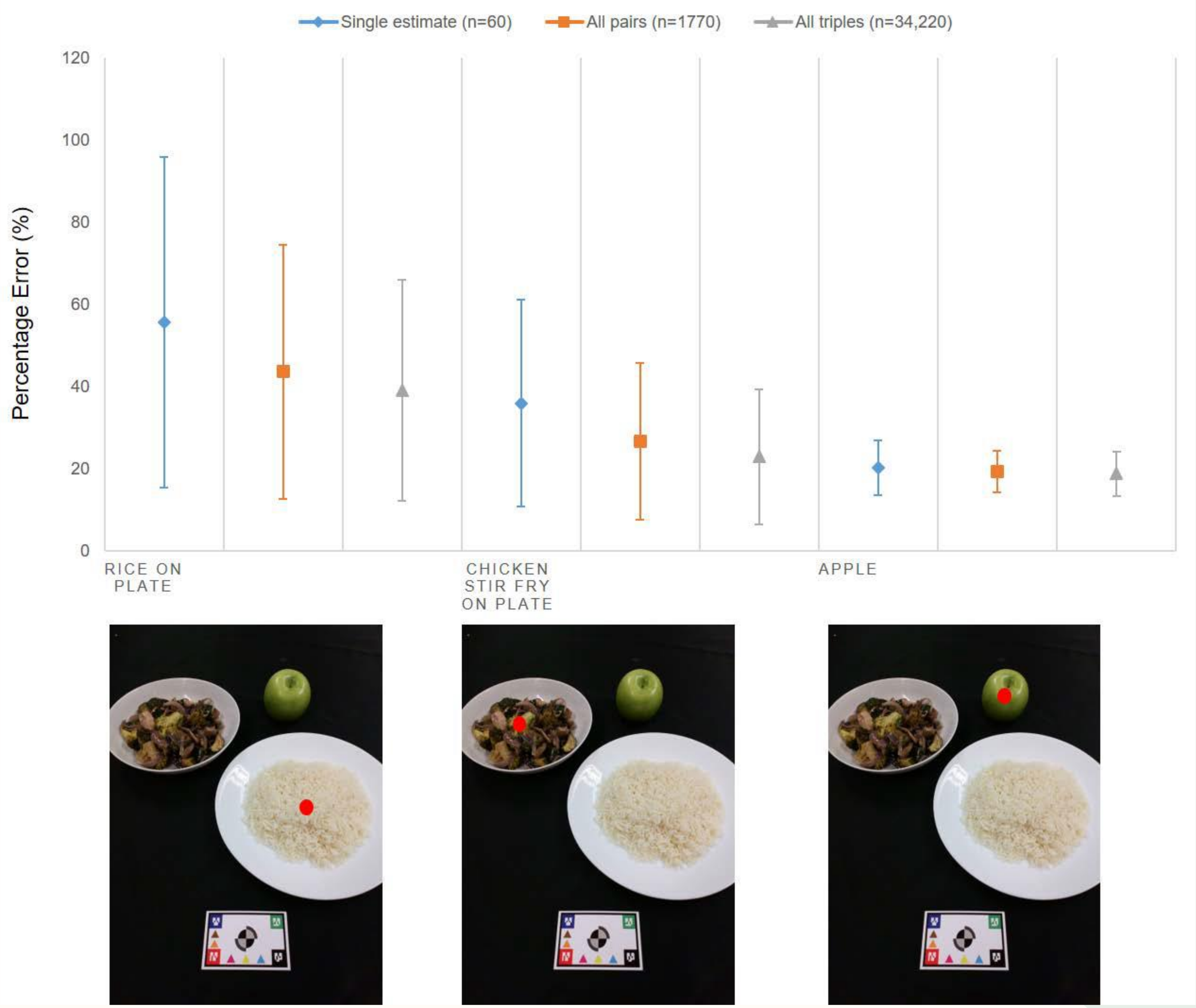
Result-Paper2

Results of the testing trials with multiple food objects on one plate. Each food item was considered individually.



Result-Paper2

Results of testing trials with multiple food objects served discretely. Each food item was considered individually.



Result-Paper3

Volume estimation.

Table 1
Volume estimation.

Scenario	Shape of food item	Actual volume (Vol_A)	Estimated volume (Vol_E)	Accuracy
1	Amorphous	270.615	299.154	90.46% [37]
2	Convex	441.036	485.14	90.9% [27]
3	Regular(square)	130	132.1	98.5% [20]
4	Regular(circle)	79.0321	78.125	98.9% [27]

Result-Paper3

State-of-art algorithms comparison with FVEstimator model

Table 2
State-of-art algorithms comparison with FVEstimator model.

Scenario	Shape of food item	Actual calories	Estimated calories	Accuracy (FVEstimator)	Accuracy existing method
1	Amorphous	660	733	90.05%	89.83% [37]
2	Convex	1078	1185	90.98%	87% [27]
3	Regular(square)	344	349.8	98.4%	99.81% [20]
4	Regular(circle)	36.718	37.145	98.9%	91% [27]

Result-Paper3

Performance evaluation representation of FVEstimator Wellness model.

Table 3

Performance evaluation representation of FVEstimator Wellness model.

Measure	Amorphous shape	Convex shape	Regular shape
Sensitivity	0.9259	0.9333	0.9836
Specificity	0.875	0.8889	0.9524
Precision	0.9091	0.875	0.9677
Negative predictive value	0.8974	0.9412	0.9756
Accuracy	0.9043	0.9091	0.9709
F1 score	0.9174	0.9032	0.9756
Matthews correlation coefficient	0.8037	0.8192	0.939
False positive rate	0.125	0.1111	0.0476
False discovery rate	0.0909	0.125	0.0323
False negative rate	0.0741	0.0667	0.0164

Discussion

Discussion

Paper	Technique	Comparison & Evaluation
Paper 1	• Convex lens imaging principle	• Mobile-based food weight estimation without specialized hardware.
		• Varying device specifications and difficulties with mixed or irregular dish remain challenges.
Paper 2	• 3D Image Projection • Manual Wire Mesh • Reference Objects	• Combination of 3D imaging and manual mesh transformations achieves high accuracy with irregular dish.
		• Requires labor-intensive processes.
Paper 3	• Pixel Per Metric Method • Reference Objects • Hemispherical Equation	• FVEstimator estimates volume for different scenarios, such as amorphous-shaped foods.
		• Its reliance on controlled datasets(predefined food) limits real-world application.

Discussion-Strengths

Mobile-based approach reduced hardware dependency, enhancing system accessibility and affordability.

Lameck Mbangula Amugongo, Alexander Kriebitz, Auxane Boch et al.(2022)

3D image approach provided high precision through user adjustments, ideal for professional settings.

Jamalia Sultana, Benzir Md Ahmed, A.K. Obidul et al.(2023)

Integrated health management model enabled calorie estimation and lifestyle support, expanding its application scope.

Fotios S. Konstantakopoulos, Eleni I. Georga, I. Fotiadis et al.(2024)

Discussion-Challenges

Sensitivity of mobile-based approach to lighting and background variations.

Lameck Mbangula Amugongo, Alexander Kriebitz, Auxane Boch et al.(2022)

Manual mesh adjustment in the 3D method may increase user burden.

Jamalia Sultana, Benzir Md Ahmed, A.K. Obidul et al.(2023)

Integrated model requires extensive data to enhance predictive accuracy.

Fotios S. Konstantakopoulos, Eleni I. Georga, I. Fotiadis et al.(2024)

Conclusion

Conclusion

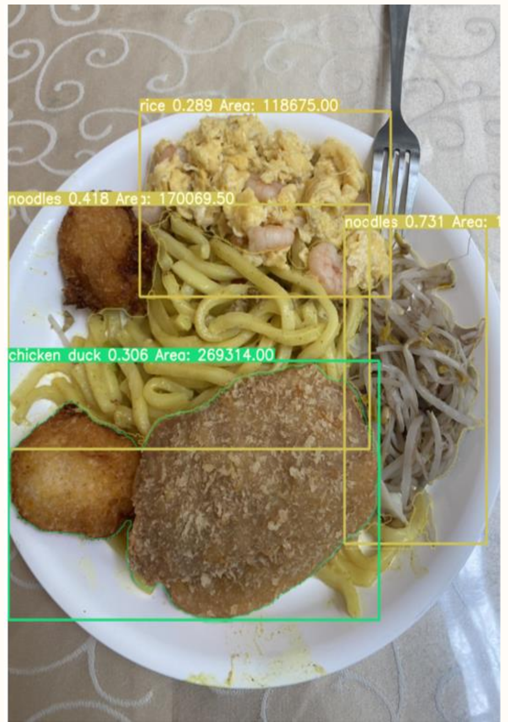
- Each method offers unique features, providing innovative solutions tailored to different application scenarios.

- These systems demonstrate how technological advancements can support precision nutrition estimation and dietary monitoring, offering new possibilities for health management

Comment

Comment

- 現行國、內外已有開發藉由圖片預測食物體積、質量以分析營養成分的應用程式，但針對微量元素與特定疾病(如腎臟相關疾病)進行飲食建議及管理，尚未發展完全。
- 就醫時的醫囑與衛教單，往往僅能提供單一化的飲食建議，且無法進行即時提醒和主動推播適合的飲食選項，讓患者難以持續追蹤及調整日常飲食；而透過食物餐盤辨識功能，除了可以提供即時且個人化的膳食建議外，更同時能促進**長期飲食管理與健康追蹤**。



Thank you!