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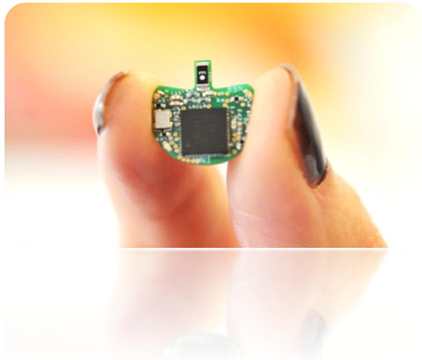
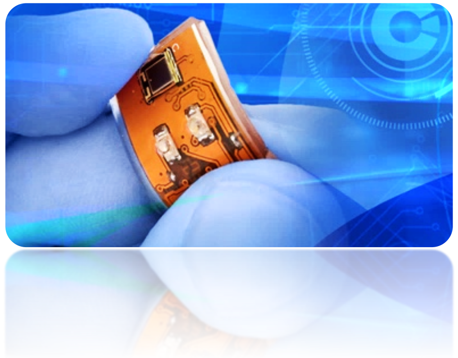
An innovative passive dietary monitoring system





Benny Lo, PhD

The Hamlyn Centre

Department of Surgery and Cancer

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The Institute of Global Health Innovation

Dietary Assessment

- 24hr recall
- Food Frequency Questionnaire (FFQ)
- Weighed food record
- Urine biomarkers
- Blood biomarkers
- Doubly labelled water

An innovative passive dietary monitoring system

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There is currently no accurate measurement of dietary intake. All current methodologies of assessing food intake have inaccuracy rates of 30-70%. Yet accurate assessment of nutritional intake is a prerequisite to define the nutritional status, nutritional needs of a population and to monitor the effectiveness of public health interventions to maintain nutritional health. To this end, it is necessary to develop tools that facilitate accurate assessment of nutritional intake in populations without affecting their normal routines. Existing dietary assessment methods are labour-intensive, expensive, and do not report nutritional intake accurately or social hierarchy of food intake. To address this gap in dietetics, the Bill and Melinda Gates Foundation funded project "An Innovative passive dietary monitoring system" aims to develop a passive dietary monitoring system for people living in Low-or-Middle Income Countries (LMICs) which does not rely on individual participation to record intake. This project focuses on both urban and rural areas in two African countries, Uganda and Ghana. To capture individual dietary intake, wearable camera technologies and fixed cameras are integrated into the system for capturing food preparation and eating activities in kitchens and dining areas. Extensive studies and field trials are being carried out in home settings in Uganda and Ghana.

Bill & Melinda Gates foundation

University of Ghana · The University of Alabama · Boston University · University of Georgia · University of Pittsburgh · CU · Baylor College of Medicine

Project overview

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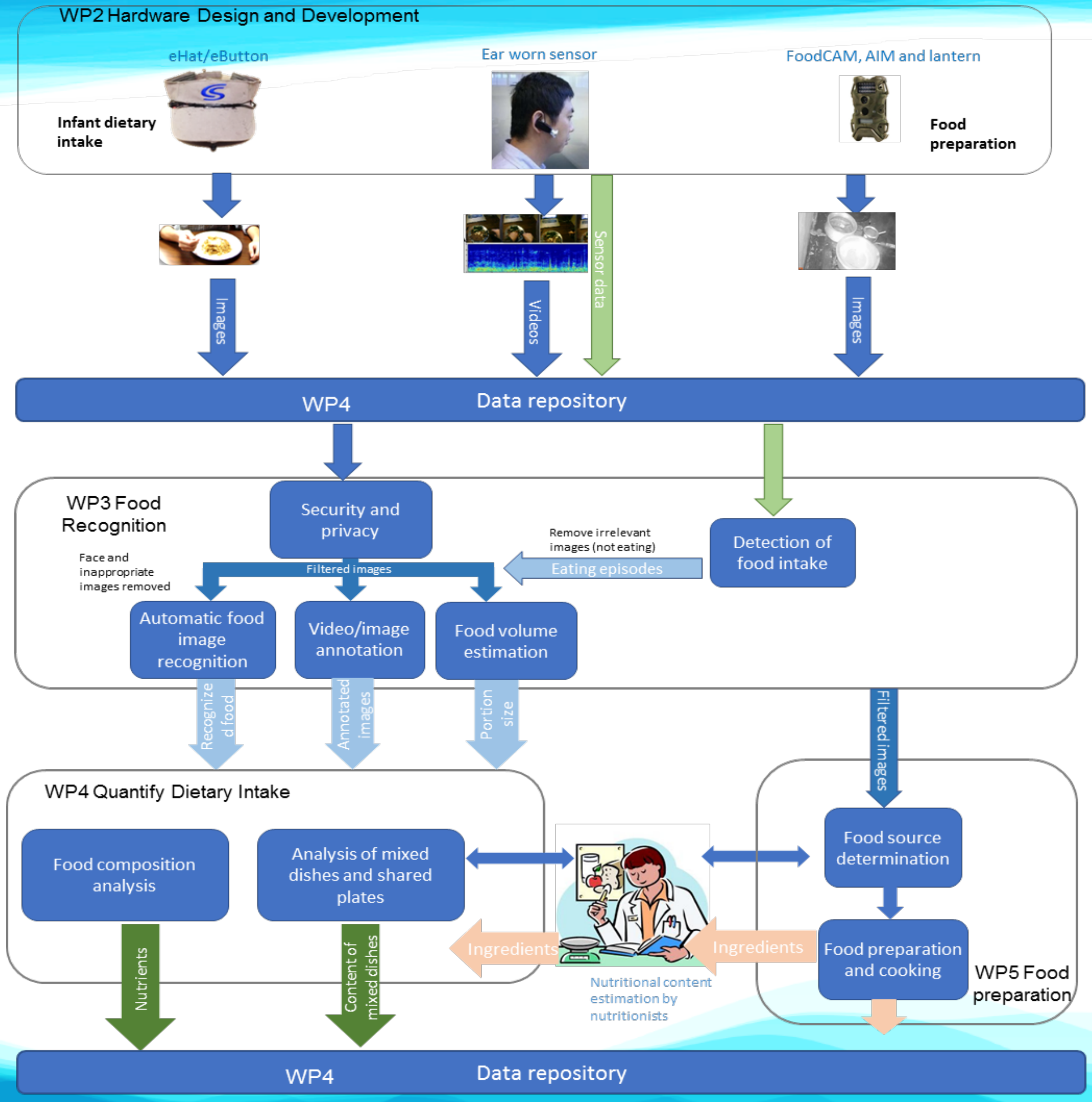

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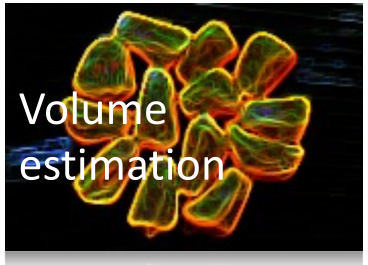
Nutrition intake estimate



Jackfruit

~200g

USDA National Nutrient Database

Nutrient	
Water (g)	146.92
Energy (kcal)	190
Protein (g)	3.44
Fat (g)	1.28
Carbohydrate (g)	46.5
Fiber (g)	3
Sugars (g)	38.16
Calcium (mg)	48
Iron (mg)	0.46
Magnesium (mg)	58
Phosphorus (mg)	42
Potassium (mg)	896
Sodium (mg)	4
Vitamin C (mg)	27.4

e-Button & e-Hat

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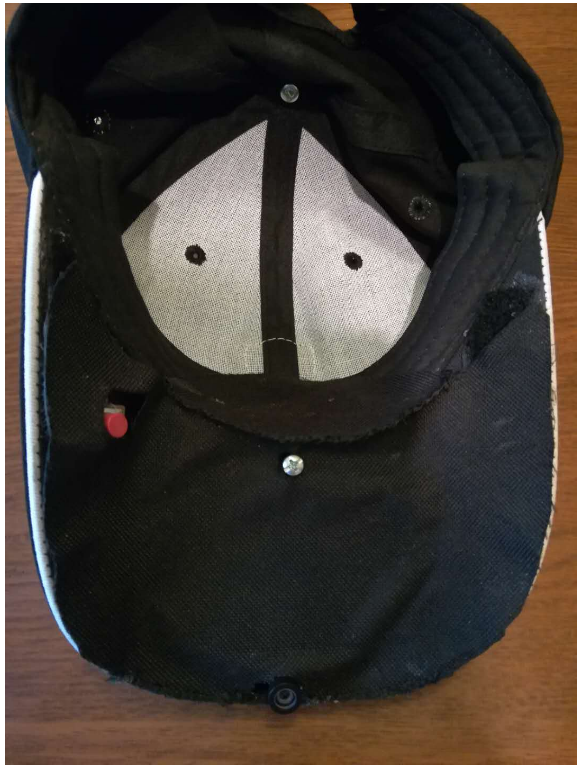
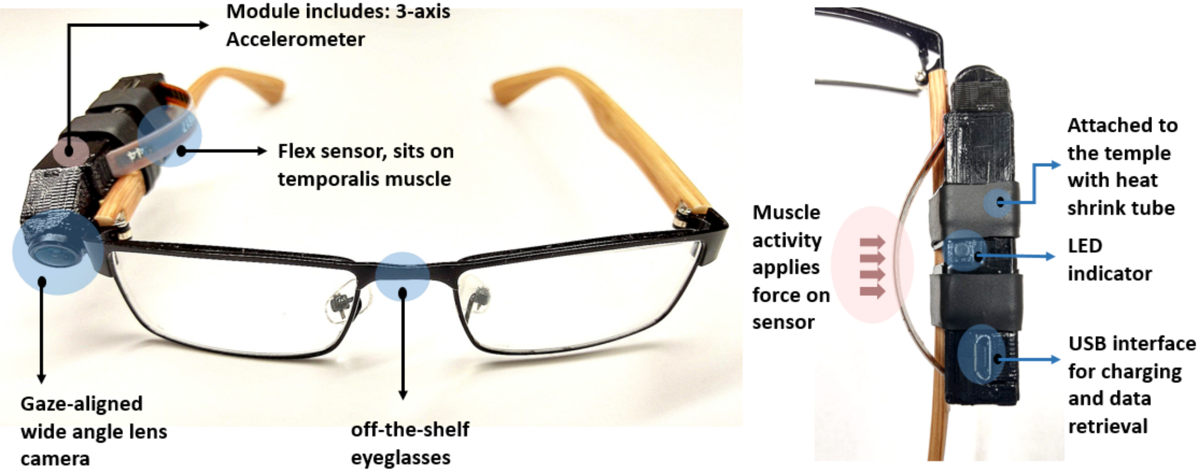


Sun, M., Fernstrom, J.D., Jia, W., Hackworth, S.A., Yao, N., Li, Y., Li, C., Fernstrom, M.H. and Sclabassi, R.J., 2010. A wearable electronic system for objective dietary assessment. Journal of the American Dietetic Association, 110(1), pp.45-47

Automatic Ingestion Monitor

AIM is a wearable device that:

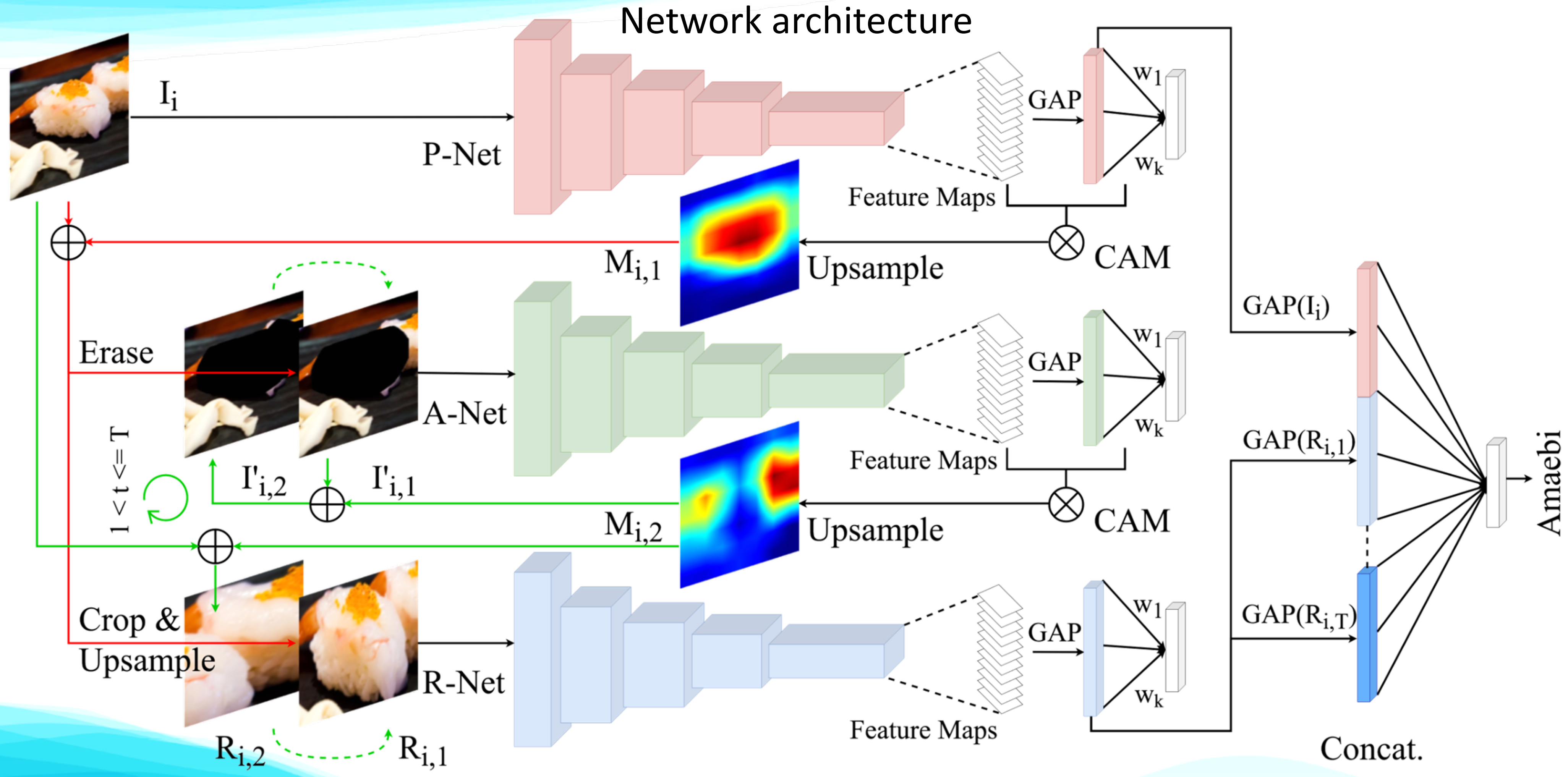
- Fully passive, does not require user actions beyond wearing
- Objectively measures when, what, how much and how we eat



Fontana, J.M., Farooq, M. and Sazonov, E., 2014. Automatic ingestion monitor: A novel wearable device for monitoring of ingestive behavior. *IEEE Transactions on Biomedical Engineering*, *61*(6), pp.1772-1779.

Food Recognition

Food Recognition



Jianing Qiu, Siyao Wang, Frank Lo, Yingnan Sun and Benny Lo, "Mining Discriminative Food Regions for Accurate Food Recognition," in the Proceedings of BMVC2019

Food Datasets

The proposed approach was tested on **two** large-scale publicly available food datasets and **one** newly proposed fine-grained food dataset.

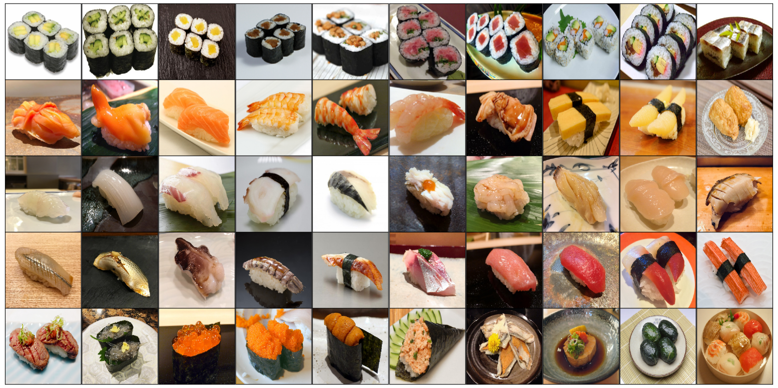
publicly available food datasets:

* Food-101 [1]: **101** common food categories and **101,000** food images in total;

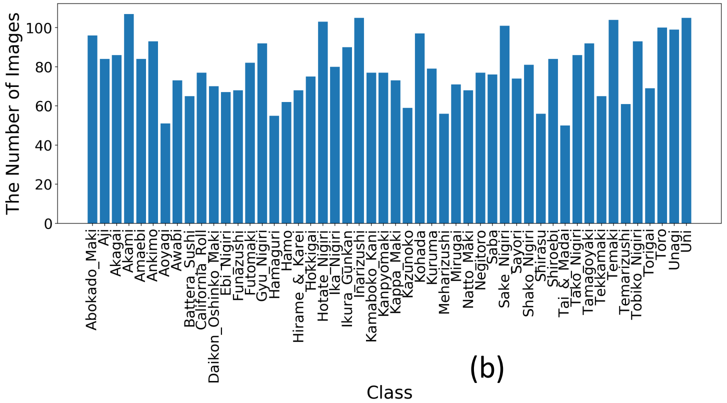
* Vireo-172 [2]: **172** Chinese food categories and **110,241** food images in total.

food dataset proposed by this paper:

* Sushi-50: **50** different sushi categories and **3,963** images in total.



(a)



(b)

(a) One sample of each category in Sushi-50. (b) The number of images of each category in Sushi-50.

Results

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- The proposed method achieves **the current best** accuracy on all three food datasets

Table 1: Comparison with other methods on the three food datasets chosen

Method	Top-1 (%)
RFDC [1]	50.76
DCNN-FOOD [3]	70.41
DeepFood [4]	77.4
Inception V3 [5]	88.28
DLA (CVPR2018) [6]	90.0
WISeR (WACV2018) [7]	90.27
DSTL (CVPR2018) [8]	**90.4**
Ours	**90.4**

Food-101

Method	Top-1 (%)
VGG [9]	80.41
Arch-D [2]	82.06
Ours	**90.2**

Vireo-172

Method	Top-1 (%)
ResNet-101 [10]	90.0
Ours	**92.0**

Sushi-50

Results

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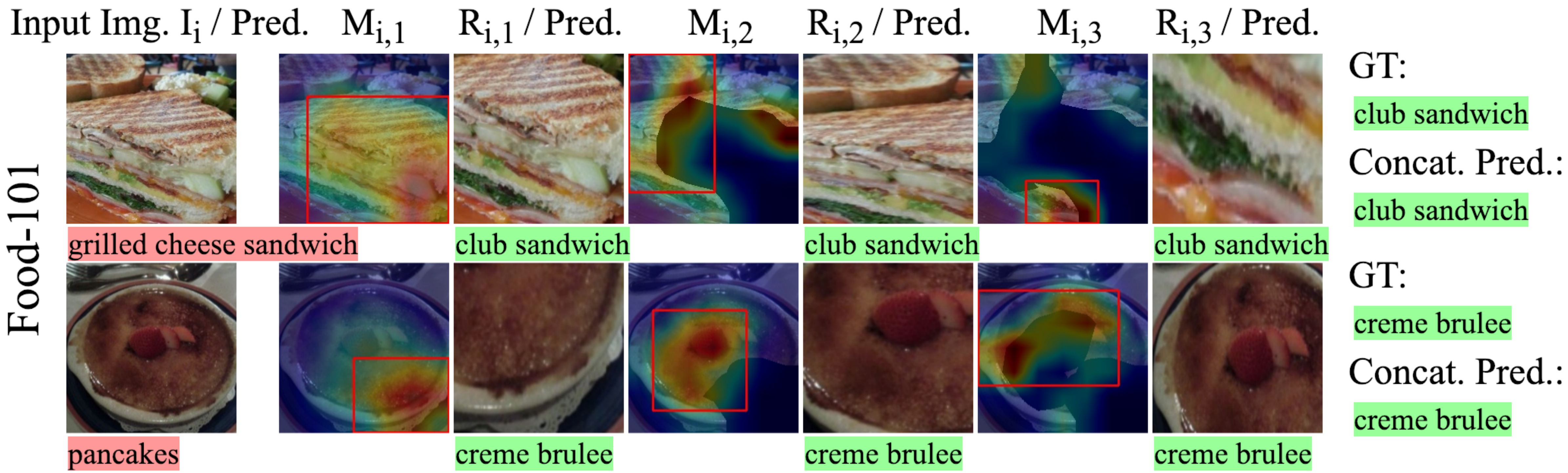

Jianing Qiu, Siyao Wang, Frank Lo, Yingnan Sun and Benny Lo, "Mining Discriminative Food Regions for Accurate Food Recognition," in the Proceedings of BMVC2019

Portion size estimate

Volume Estimation - deep learning view synthesis

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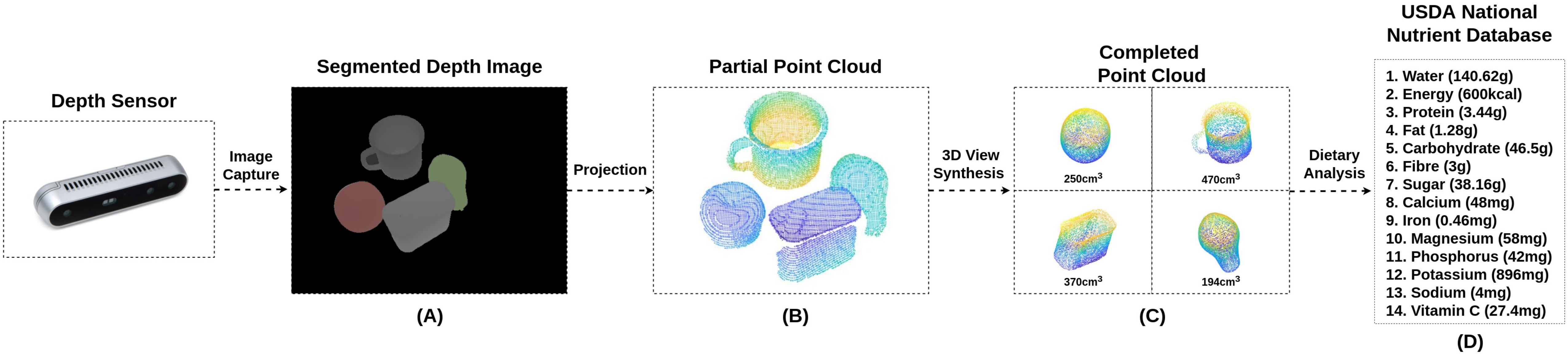

Po Wen Lo, Yingnan Sun, Jianing Qiu, Benny Lo, ”Food Volume Estimation based on Deep Learning View Synthesis from a Single Depth Map”, Nutrients 2018, 10(12), 2005;

Volume Estimation

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Detailed information

- A stereo or depth sensor is required to capture an image from any convenient viewing angle and position.
- Each food item is segmented out through a segmentation method.
- The depth image is converted from image coordinate to camera coordinate so that the partial point cloud of each food item
- Point completion network is applied.

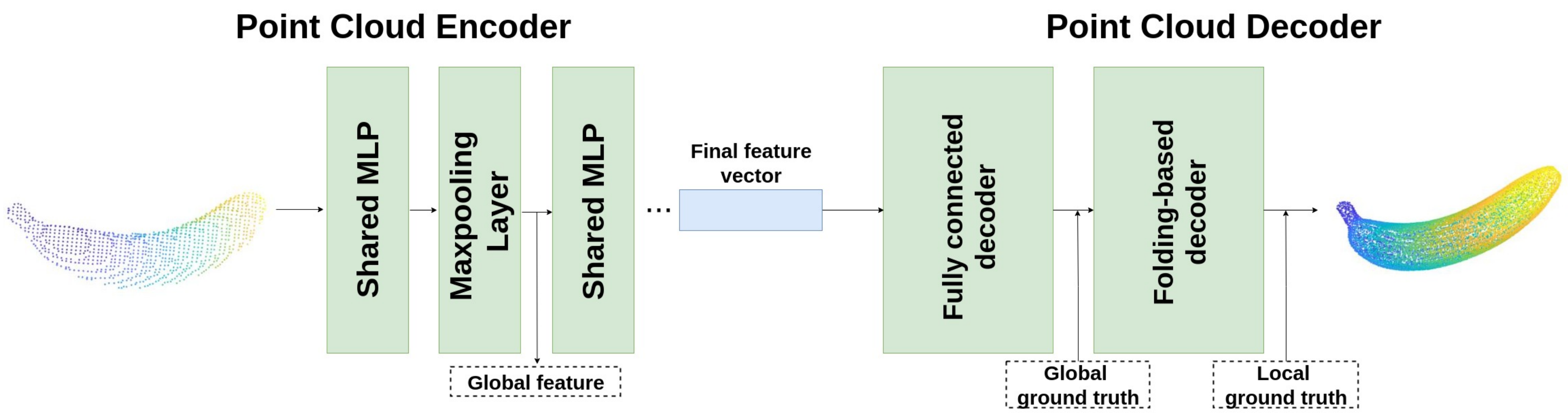

Figure: The network architecture of the point completion network

Po Wen Lo, Yingnan Sun, Jianing Qiu, Benny Lo, "Food Volume Estimation based on Deep Learning View Synthesis from a Single Depth Map", Nutrients 2018, 10(12), 2005;

A Vision-based Dietary Assessment Approach using View Synthesis

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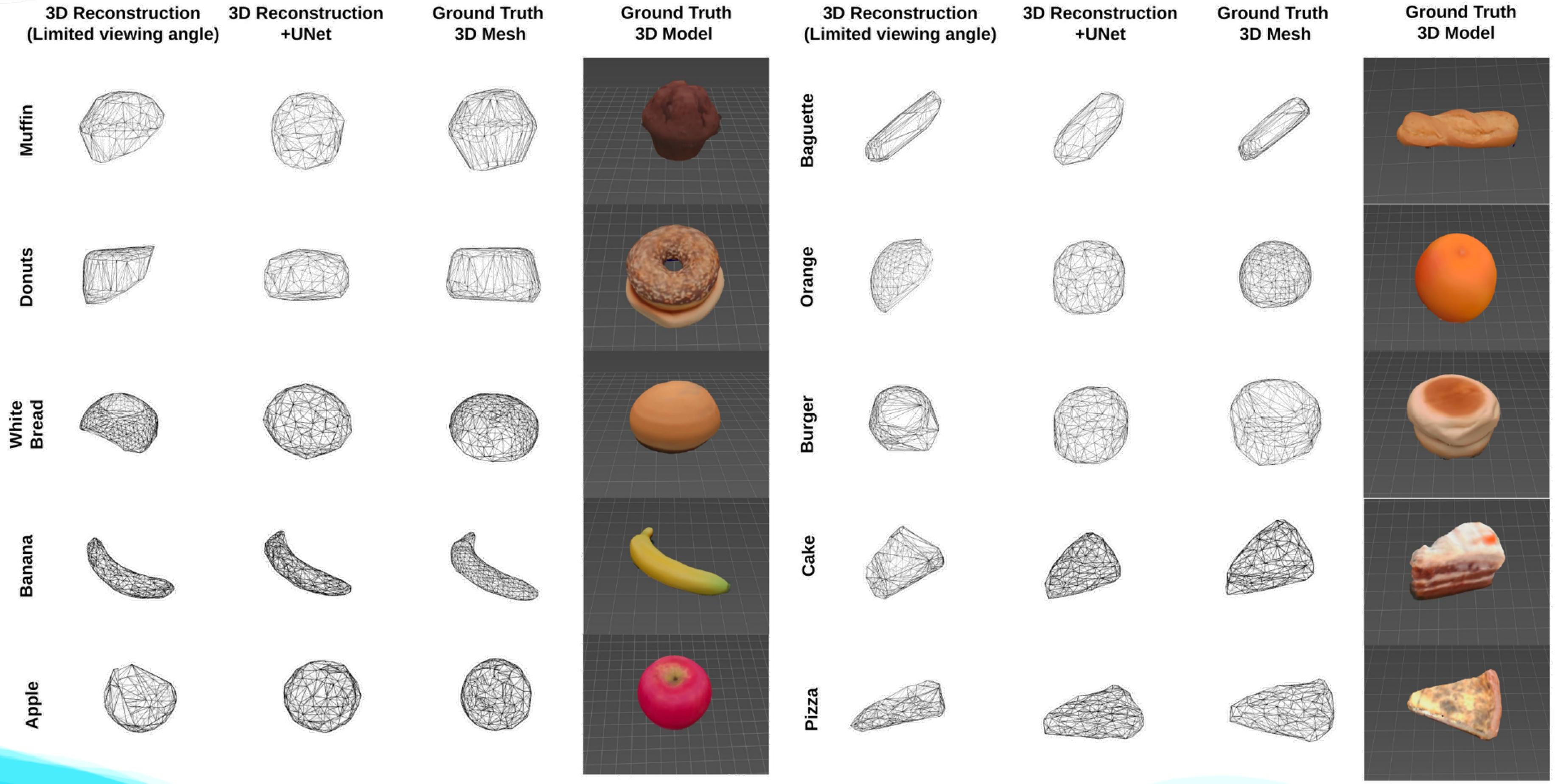
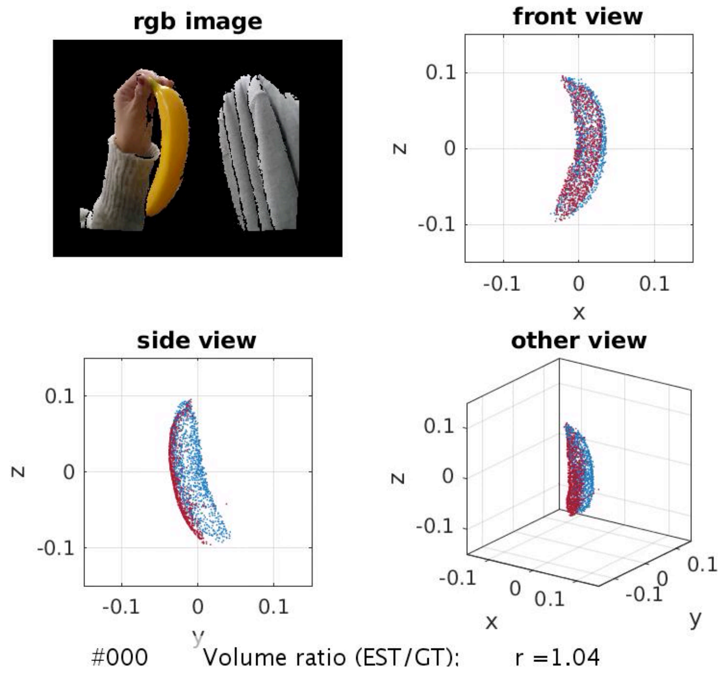
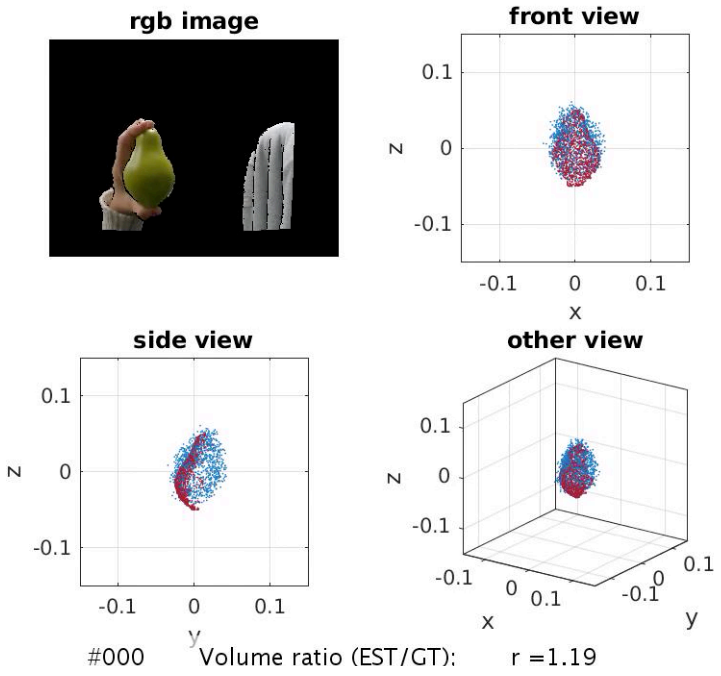
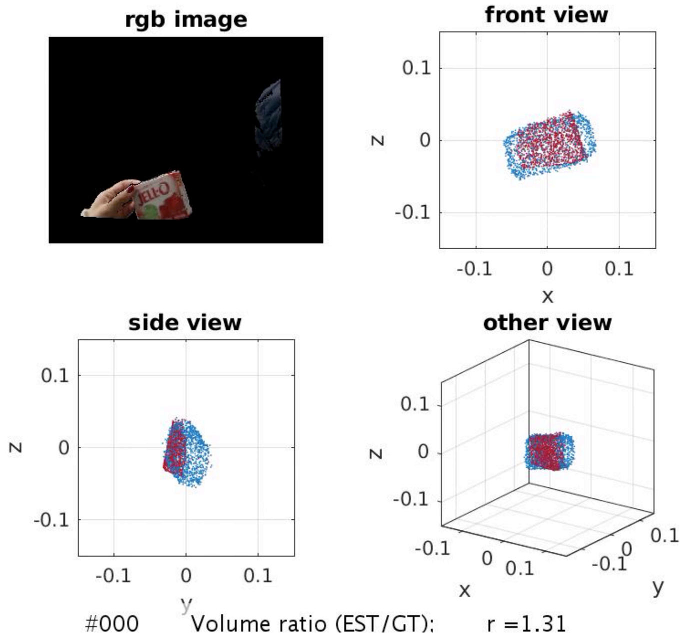


Po Wen Lo, Yingnan Sun, Jianing Qiu, Benny Lo, "Food Volume Estimation based on Deep Learning View Synthesis from a Single Depth Map", Nutrients 2018, 10(12), 2005;

Volume Estimation in Real World Scenarios







Po Wen Lo, Yingnan Sun, Jianing Qiu, Benny Lo, "Food Volume Estimation based on Deep Learning View Synthesis from a Single Depth Map", Nutrients 2018, 10(12), 2005;

Communal eating/ Shared plate

Communal eating/Shared plate

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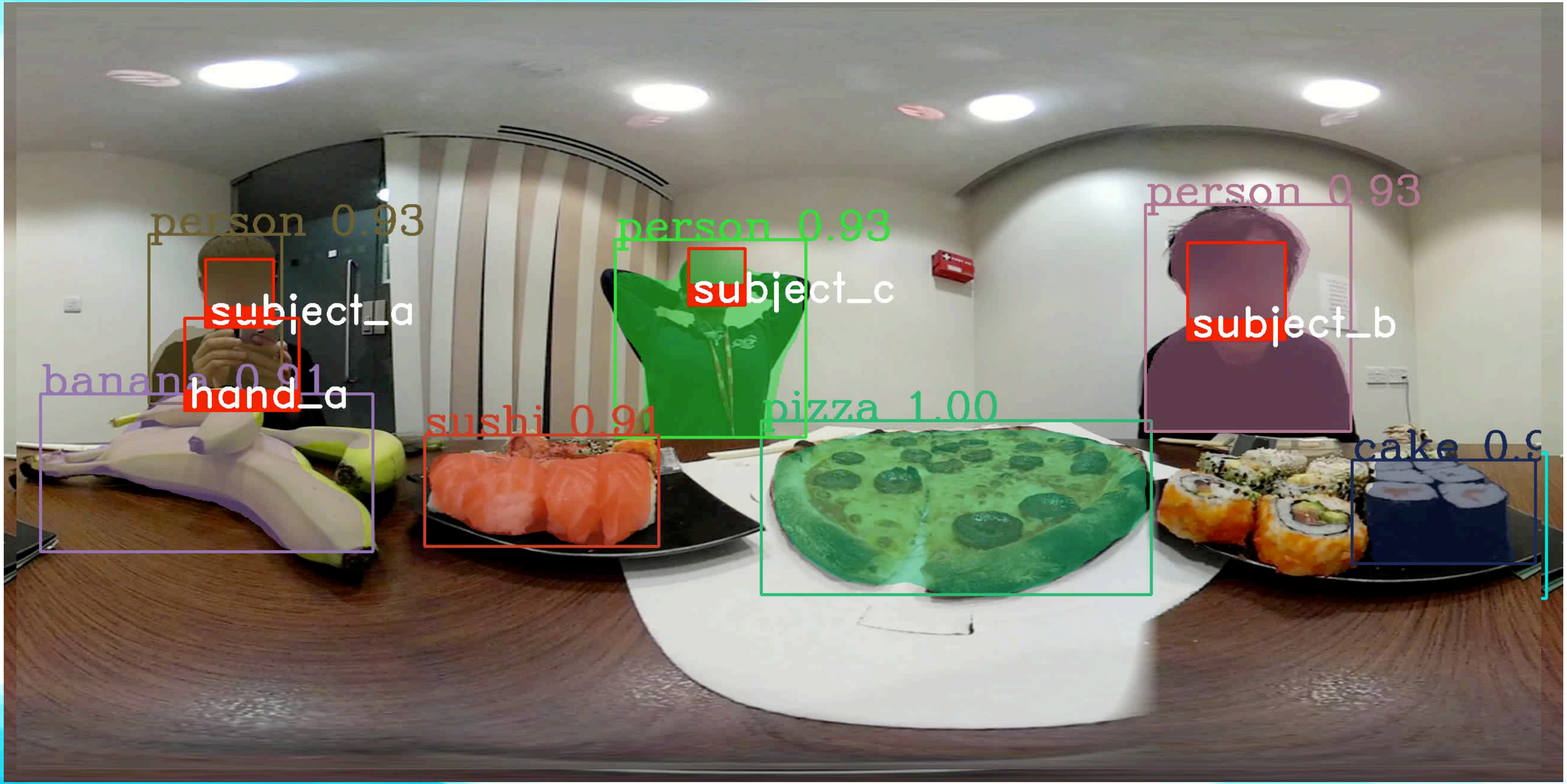
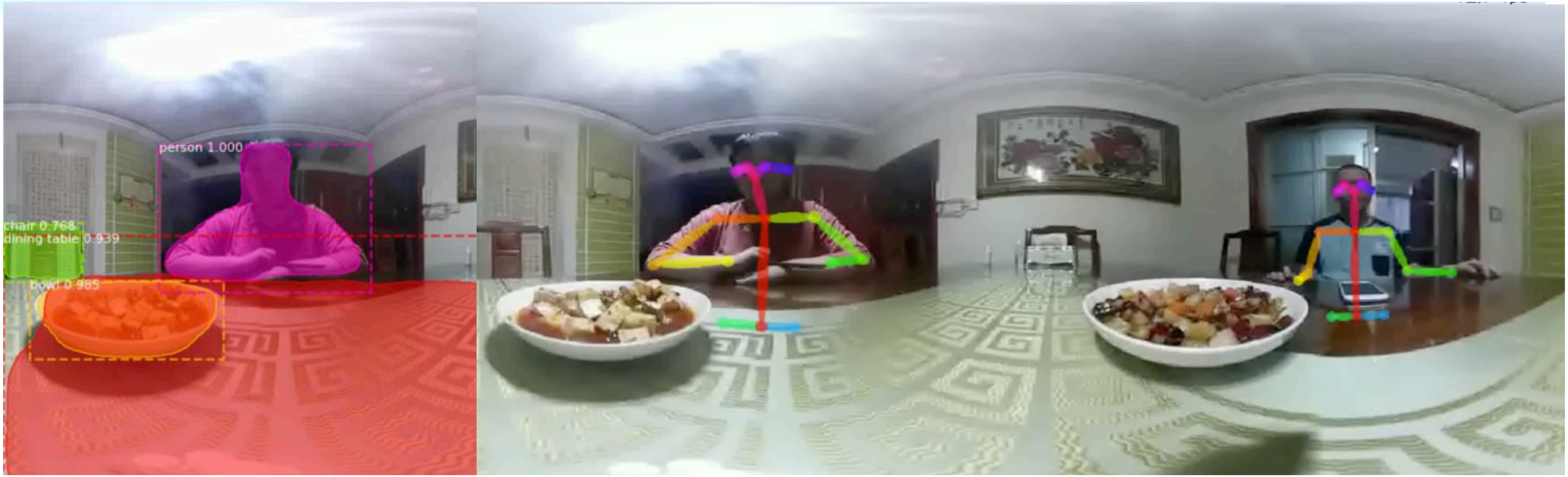


Jianing Qiu, Frank Lo and Benny Lo, "Assessing Individual Dietary Intake in Food Sharing Scenarios with a 360 Camera and Deep Learning" BSN 2019

Communal eating/Shared plate



Studies

Studies

- Study 1: Laboratory validation of food intake estimation devices
- Study 2: Acceptability and feasibility in the field
  - Phase 1: Household food behavior
  - Phase 2: Pre-field test data gathering prior to the preliminary field test:
    - Acceptability of the devices
    - Preliminary field test for acceptability, reliability and performance of recording devices
- Study 3: Field validation studies in Uganda and Ghana
  - Phase 1: Preliminary field data (~4 households at each site (~ 16 in total) lasting one day)
  - Phase 2: System validation in target populations (in ~22 households at each site (~88 in total) lasting three consecutive days)

Study 1: Laboratory validation of food intake estimation devices

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Food images captured by eButton

Food images captured by Glass-worn device

Study 2: Acceptability and feasibility in the field

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in households in Ghana

- Identify and solve field relatedTo assess the feasibility, acceptability and general performance of devices challenges
- Completeness of data collection
  - Clarity of food related images

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Phase 2 of Study 2

- Feasibility of passive devices in dietary assessment
  - Consent and device demonstration
  - Day 1 - Introduction and demonstration of devices to households
  - Day 2- Devices worn and installed for data collection
  - Day 3 - Independent field assistant conducted device assessment
    - 24-hour dietary recall
  - Day 4 - Repeat of Day 2 activities
    - 24-hour dietary recall
    - Weighed food intake

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Study 2: Data collected in Ghana

- Examples of eButton images (containing foods)









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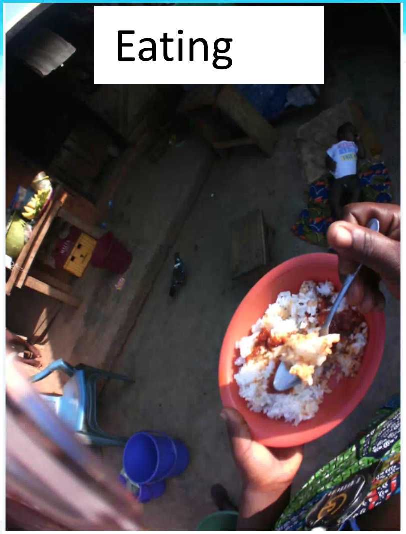
Study 2:

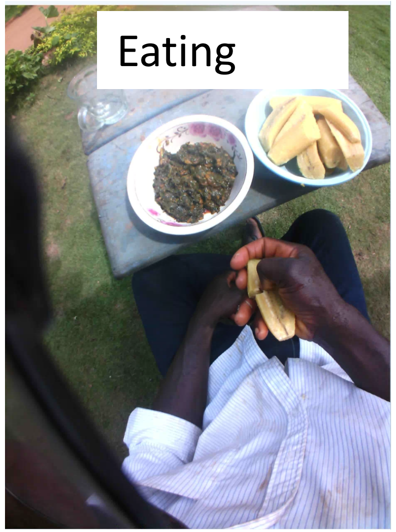
(Sample Images captured by) AIM

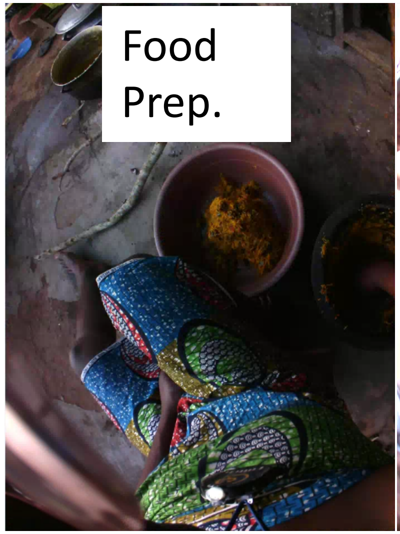

Eating

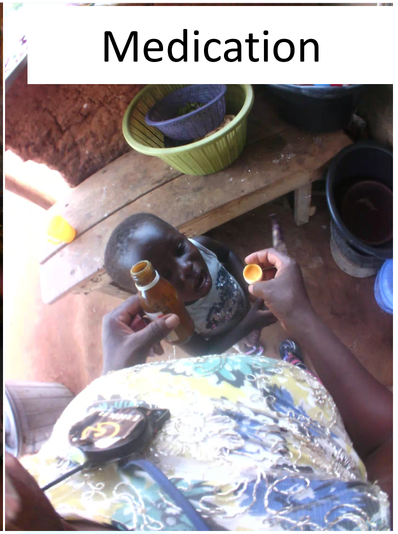

Food Prep


Shared Meal


Cooking


Eating


Food Prep.


Medication

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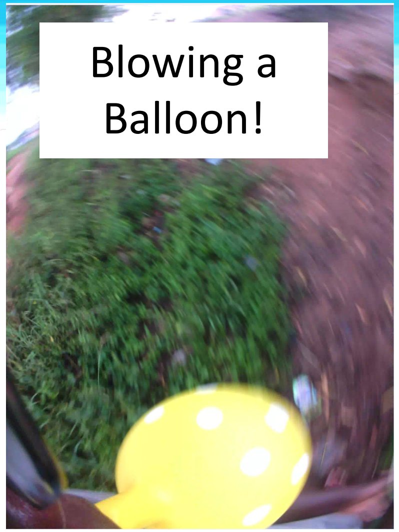
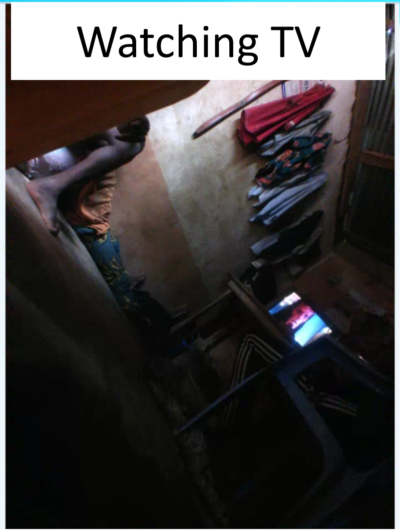
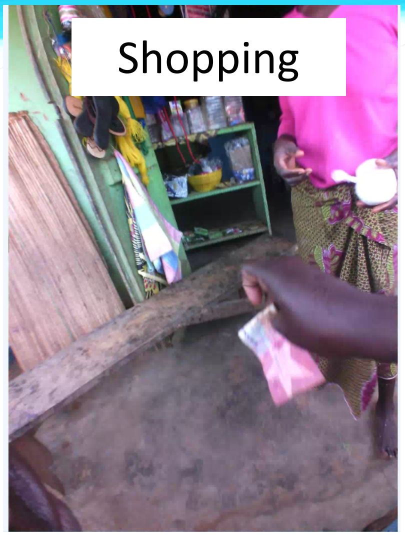
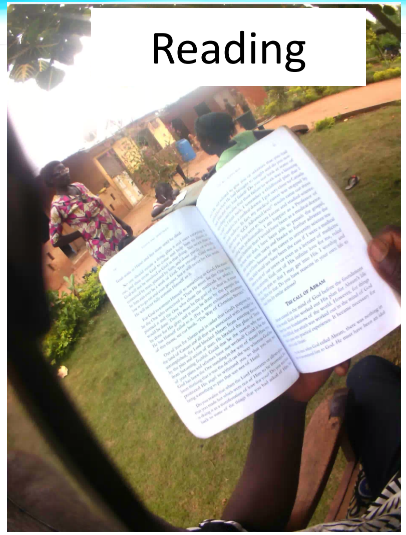
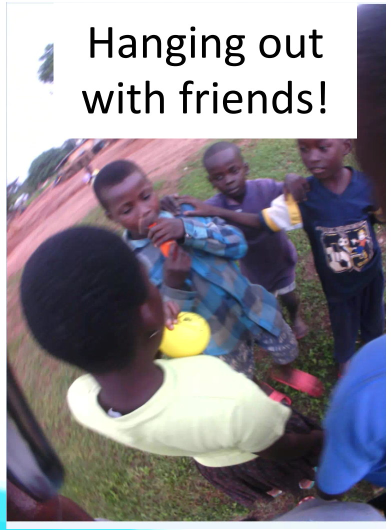
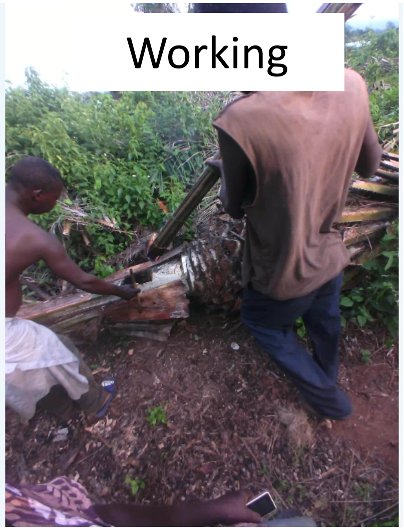

Blowing a Balloon!


Watching TV

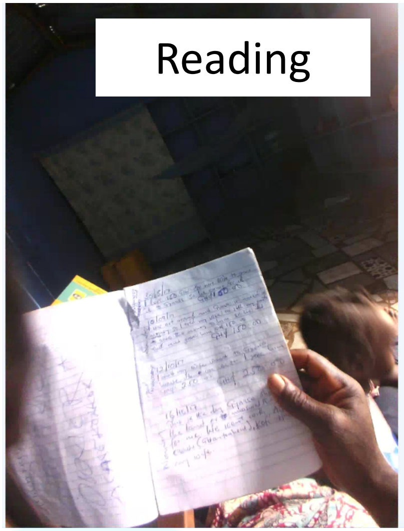

Shopping


Reading


Hanging out with friends!


Working


Shopping


Reading

Challenges

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- Ethics
- Device issues
- Wearability
- Image and lighting
- User compliance
- Vast amount of data
- COVID-19

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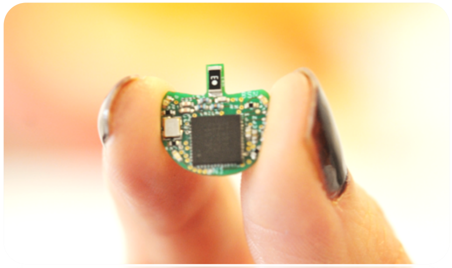

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