Dietary Assessment – moving from paper to the digital domain

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Outline

- Application to the Nutrition Care Process

- Introduction to image analysis

- Validation studies - results of first phase studies

- Survey of methods under development
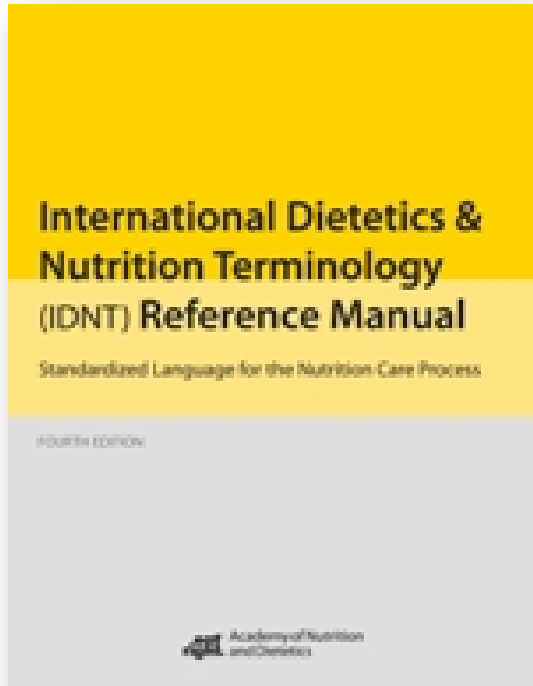
- Tips for considering use of mobile devices

Nutrition Care Process & Model
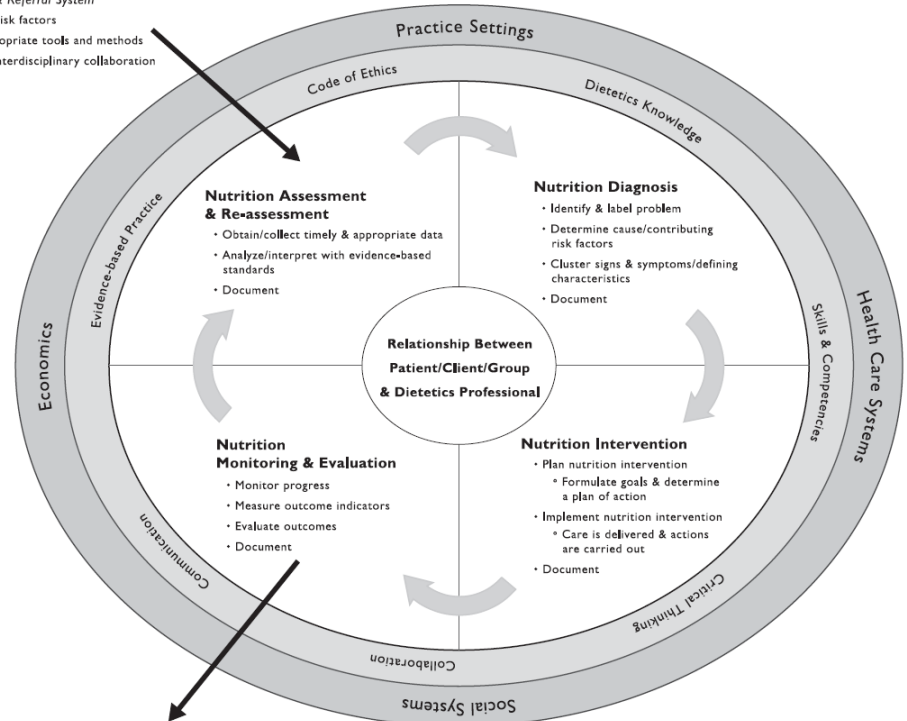

International Dietetics & Nutrition Terminology (IDNT) Reference Manual — Standardized Language for the Nutrition Care Process. FOURTH EDITION. Academy of Nutrition and Dietetics.

The Nutrition Care Process and Model

Screening & Referral System
- Identify risk factors
- Use appropriate tools and methods
- Involve interdisciplinary collaboration

Nutrition Assessment & Re-assessment
- Obtain/collect timely & appropriate data
- Analyze/interpret with evidence-based standards
- Document

Nutrition Diagnosis
- Identify & label problem
- Determine cause/contributing risk factors
- Cluster signs & symptoms/defining characteristics
- Document

Relationship Between Patient/Client/Group & Dietetics Professional

Nutrition Monitoring & Evaluation
- Monitor progress
- Measure outcome indicators
- Evaluate outcomes
- Document

Nutrition Intervention
- Plan nutrition intervention
  - Formulate goals & determine a plan of action
- Implement nutrition intervention
  - Care is delivered & actions are carried out
- Document

Outcomes Management System
- Monitor the success of the Nutrition Care Process implementation
- Evaluate the impact with aggregate data
- Identify and analyze causes of less than optimal performance and outcomes
- Refine the use of the Nutrition Care Process

Outer rings: Practice Settings, Dietetics Knowledge, Health Care Systems, Skills & Competencies, Critical Thinking, Social Systems, Collaboration, Communication, Economics, Evidence-based Practice, Code of Ethics

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Source: http://www.eatright.org

NCP Steps

1. Nutrition Assessment

2. Nutrition Diagnosis

   – PES statement

   – **P**roblem, **E**tiology, **S**igns/Symptoms

   – Consider the intake domain as the preferred problem

3. Nutrition Intervention

4. Nutrition Monitoring and Evaluation

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Assessment				
Food/Nutrition History	**Biochemical Data, Medical Tests, and Procedures**	**Anthropometric Measurements**	**Physical Examination Findings**	**Client History**
Food and nutrient intake, nutrition related knowledge and practices, etc.	Laboratory data (e.g., glucose) and tests (e.g., REE), etc.	Height, weight, rate of weight change, etc.	Oral health, physical appearance, etc.	Medication use, medical / health history, etc.

Diagnosis		
Intake	**Clinical**	**Behavioral-Environmental**
Too much or too little of a food or nutrient compared to actual of estimated needs.	Nutrition problems that relate to medical or physical conditions.	Knowledge, attitudes, beliefs, physical environment, access to food, or food safety.

Intervention			
Food and/or Nutrient Delivery	**Nutrition Education**	**Nutrition Counseling**	**Coordination of Nutrition Care**
An individualized approach for food / nutrient provision, including meals and snacks…	A formal process to instruct or train…or modify food choices and eating behavior…	A supportive process…create individualized action plans…	Consultation with, referral to…that can assist in treating or managing …problems

Monitoring & E			
Nutrition-related Behavioral and Environmental Outcomes	**Food and Nutrient Intake Outcomes**	**Nutrition-Related Physical Sign and Symptom Outcomes**	**Nutrition-Related Patient/Client-Centered Outcomes**
Nutrition-related knowledge…impact food and nutrient intake.	Food and/or nutrient intake from all sources.	Anthropometric, biochemical, and physical …indices.	Perception of patient/client's nutrition intervention…

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NCP Snapshot

Source: eatright.org

Assessment	Food/Nutrition History	Biochemical Data, Medical Tests, and Procedures	Anthropometric Measurements	Physical Examination Findings	Client History
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Monitoring & E	Nutrition-related Behavioral and Environmental Outcomes	Food and Nutrient Intake Outcomes	Nutrition-Related Physical Sign and Symptom Outcomes	Nutrition-Related Patient/Client-Centered Outcomes
	Nutrition-related knowledge…impact food and nutrient intake.	Food and/or nutrient intake from all sources.	Anthropometric, biochemical, and physical …indices.	Perception of patient/client's nutrition intervention…

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NCP Snapshot

Source: eatright.org

Nutrition Assessment Matrix

- Food/Nutrition-Related Nutrition Diagnostic Terminology
  - 31 parameters
  - Food & Nutrient Intake (one of the parameters)
  - Nutrition Diagnostic Terminology (NDT)
    - e.g., NI 1.5. Excess intake of energy…
  - A total of 53 NDTs for Food & Nutrient Intake

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Issues with paper-based methods?

- Burden on the client

- Analysis time for the practitioner

- Measurement error

There must be a better way…

- Dietary assessment among adolescents is problematic
- Ages 11-14 years is particularly challenging
  - Novelty of recording food has worn off
  - Assistance from parents is no longer welcome

Livingstone MBE, et al Br J Nutr 2004; 92(suppl2): S213-S223.

"Go home and take pictures of the food you eat"

30 boys & girls
10 - 14 y

Sample images

Before and after

Cooperation using camera

	Camera food record kept for:		
	0 day	1 day as requested	2 days, more than requested
Number of children (n=30)	1	6	23

Boushey, *et al*, Eur J Clin Nutr 2009

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Responses as % about preferences for dietary assessment methods (n=29)

Response to "*I liked…*"	Food record	24 hr recall	PDA tree	PDA search	Camera	PDA camera
Agree	35	52	38	75	100	100
Neutral	31	21	34	14	0	0
Disagree	35	28	28	11	0	0

Boushey, *et al*, Eur J Clin Nutr 2009

Study Design

24- hour schedule

n=15

19 Unique foods served
Cheeseburger Sandwich
Chocolate Cake, Iced
Coke
Eggs, Scrambled
French Dressing
French Fries
Garlic Bread, toasted
Lettuce, romaine mix
Margarine
Milk, 2%
Orange Juice
Peach, canned slices
Pear, canned halves
Sausage Links
Spaghetti with Sauce, Cheese
Strawberry Jam
Sugar Cookie
Tomato Catsup
White Toast

Total 330 foods

Day 1	n		Day 2
8:00 am Pick up **Breakfast**	7	S	8:00 am Return home
Lunch	7	N A C K S	
Dinner	8		
	22		

S N A C K S

Training Image	→	Segmentation	→	Feature Extraction	→	Build Vocabulary Tree and Train Classifier

Test Image	→	Segmentation	→	Feature Extraction	→	Classification

- Food Type (Label)
- Labeled Segmented Images (Area Estimates)

- Training images – groundtruth images
- Segmentation – interactive version and automatic version using Normalized Cut
- Features – color, texture, shape, SIFT
- Classification – Bag of Features and SVM

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24hr Database – Breakfast

Ground Truth

Automatic

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010

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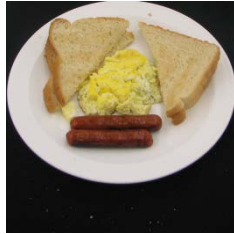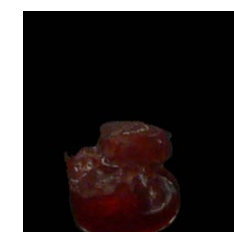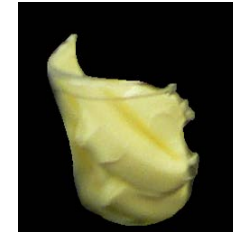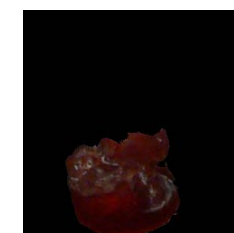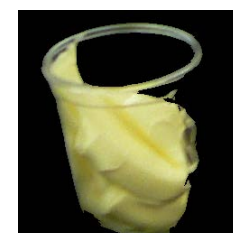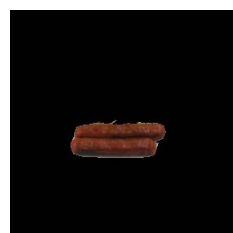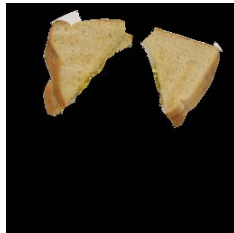
24hr Database – Lunch

Ground Truth

Automatic

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010

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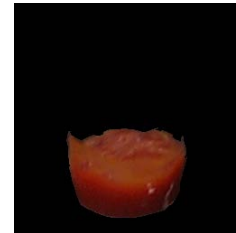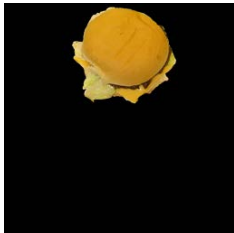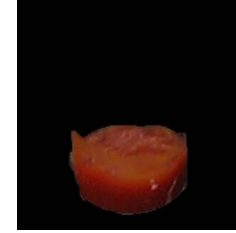
24hr Database – Dinner

Ground Truth

Automatic

19
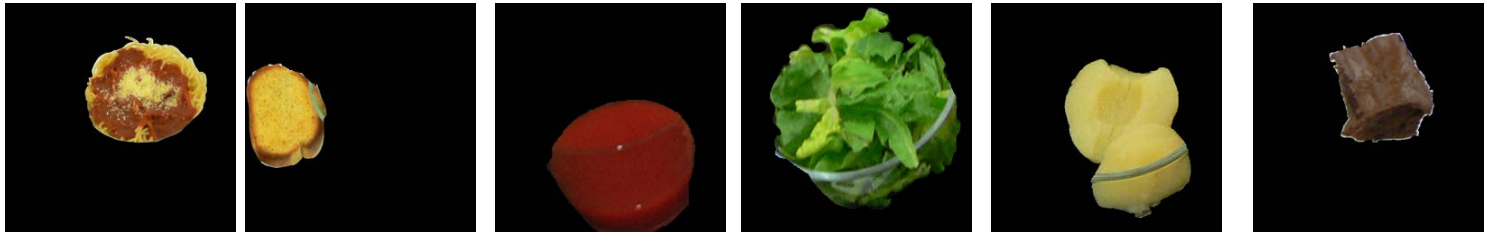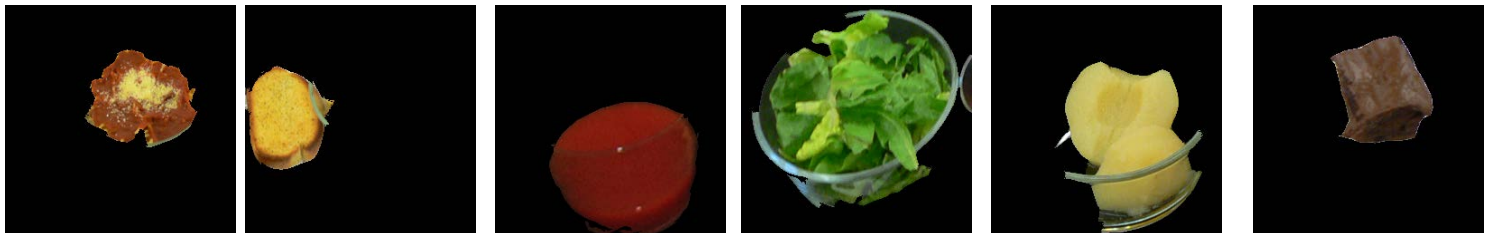
Classification Accuracy of Food Items

Percentage of Training Data	Correct Classification Percentage
10	88.1
25	94.4
50	97.2
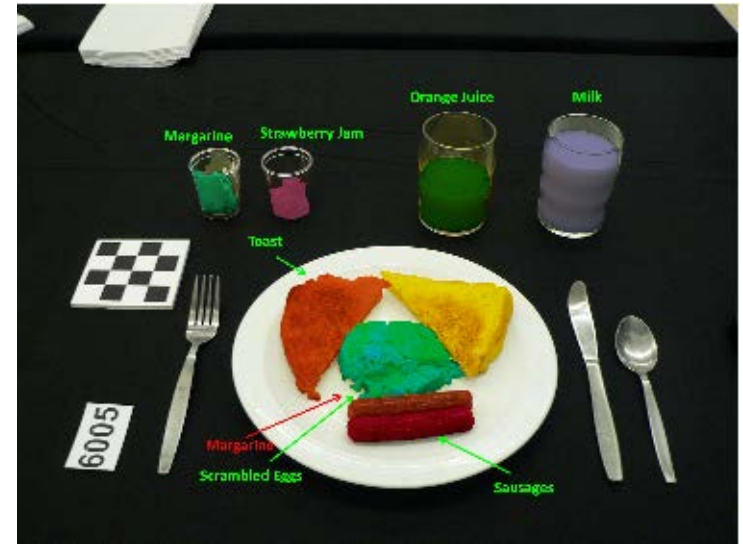
Scrambled eggs - 10% training	70%	30% (Margarine)
Scrambled eggs - 25% training	78%	22% (Margarine)
Scrambled eggs - 50% training	87%	13% (Margarine)

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010

Volume Estimation

Food Volume Estimation

Camera Calibration → **Volume Estimation** (Feature point extraction, 3D volume reconstruction) → **Nutrient Computation**

Input → Camera parameters → Best fit template → Shape templates search (Lookup Table) → Food code (FNDDS) → Volume estimate

Nutrient Facts
Weight(g) 175.93
Cal(kcal) 82.69
Fat(g) 0.21
Pro(g) 1.65
Ca(mg) 70.73
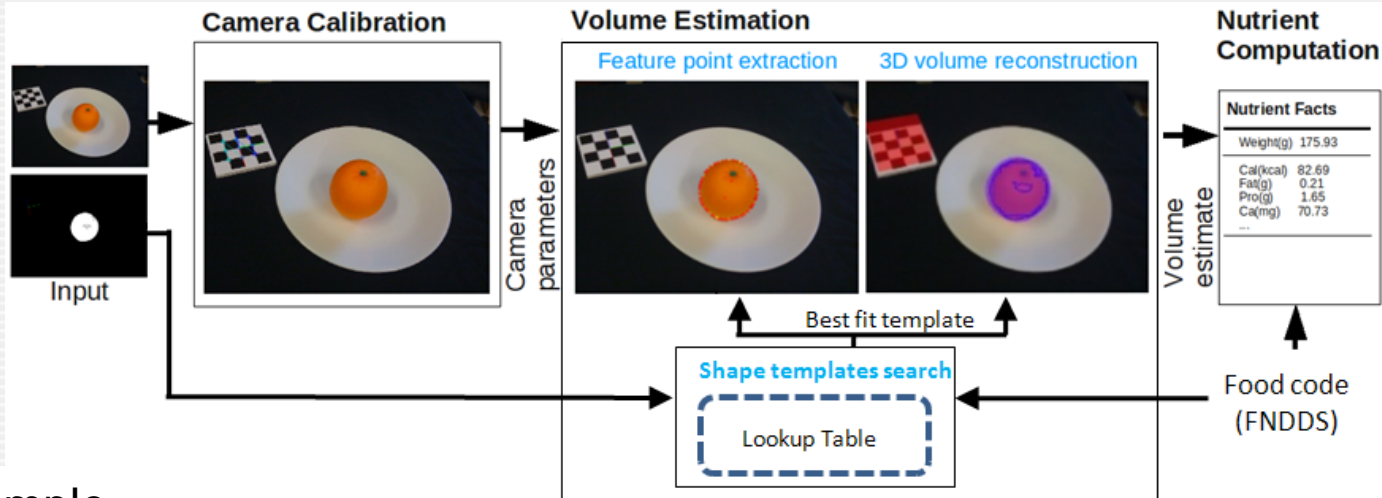
Example

Input datasets
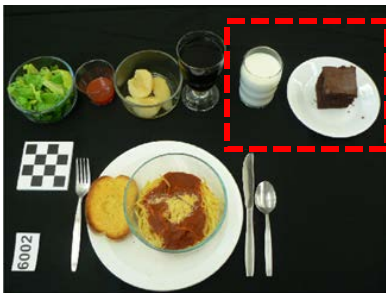
- Meal image
- Segmented images
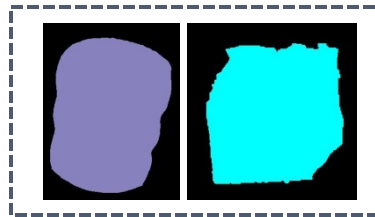
Food Code
- 11112110 (Milk)
- 53105500 (Chocolate cake)

Results

- Best-fit shape templates
  - Geometrical class: Cylindrical shape
  - Geometrical class: Box shape

- Extracted feature points ● Estimated volumes

Woo et al. Electrical Imaging Science and Technology, 2010
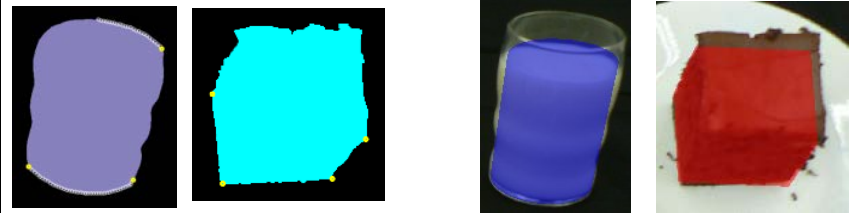
Food Items

1. Sausage Links
2. Spaghetti w/ sauce, cheese
3. French dressing
4. Milk, 2%
5. Cheeseburger sandwich
6. Strawberry jam
7. Orange juice
8. Ketchup
9. Sugar cookie
10. Chocolate cake w/ icing
11. Coke
12. Margarine
13. Toast
14. Sliced peaches
15. Scrambled eggs
16. Pear halves
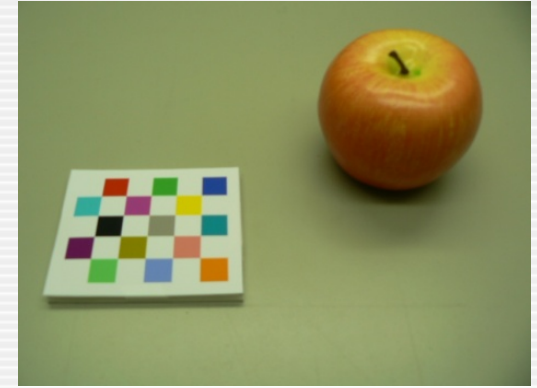17. French fries
18. Garlic bread
19. Lettuce salad

Weight and energy error using volume image analysis by food from images taken by 15 adolescents (11-18 y) over a 24-hour period

♦ % of known gram weight   ■ Mean energy difference (kcal)
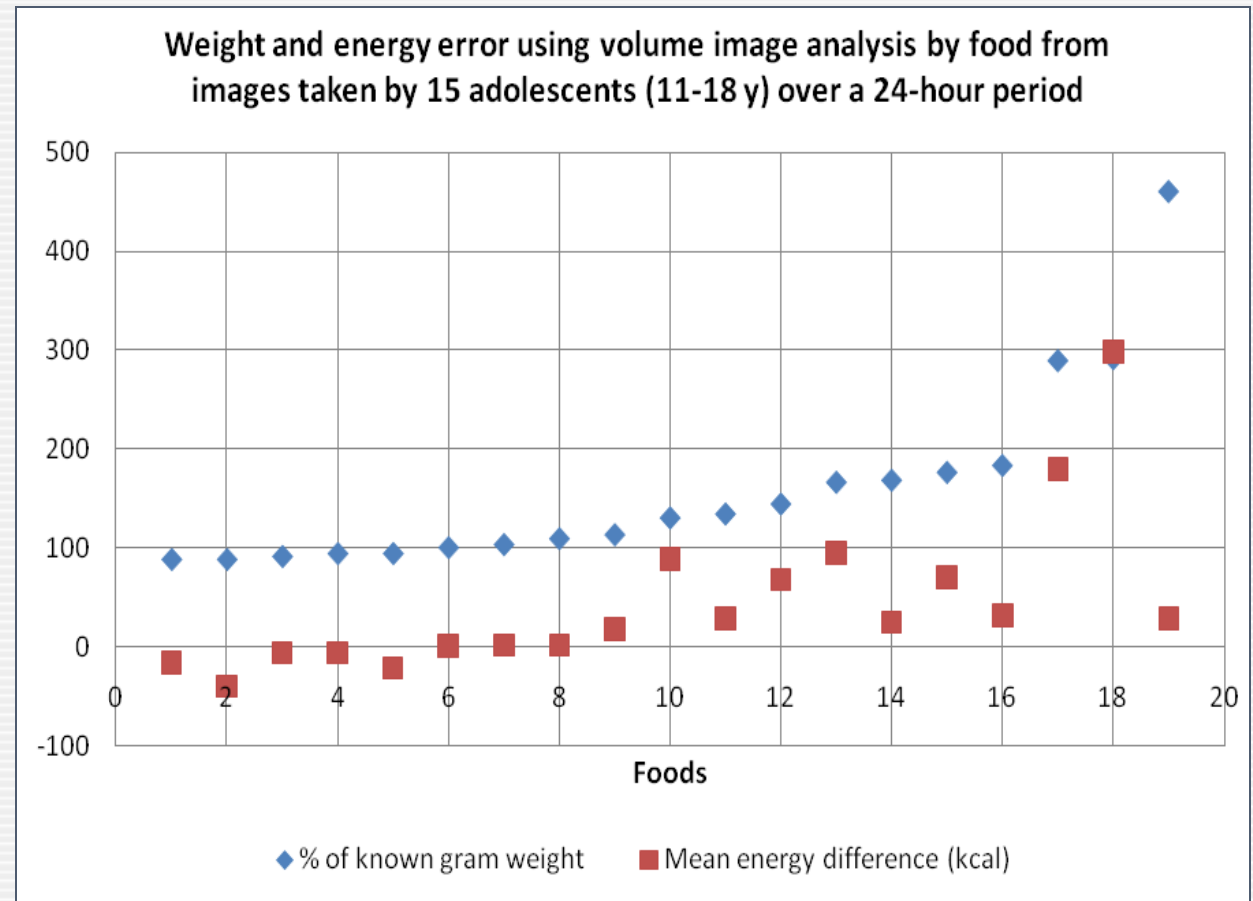
Color Fiducial Marker

Reference Illumination
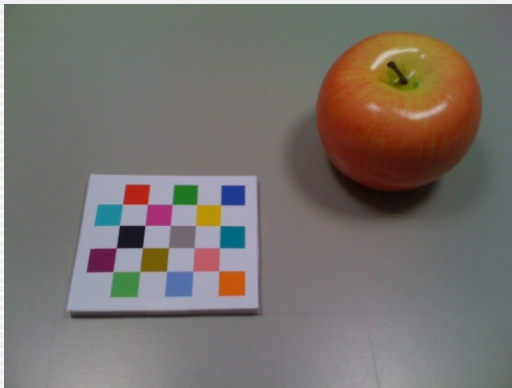
New Illumination #1
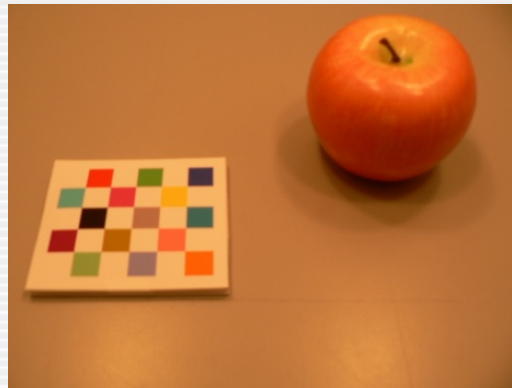
New Illumination #2

Color Correction
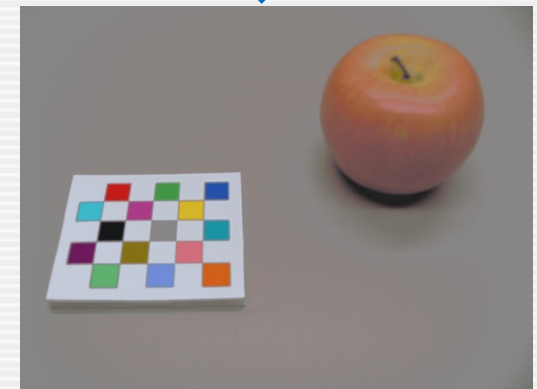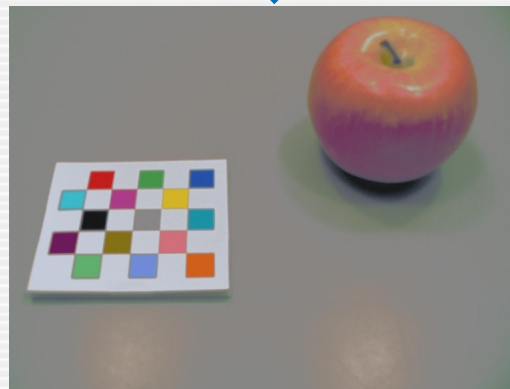
CELL PHONE TIMELINE

1992	1994	1996	1997	1999
Motorola MicroTac	Motorola StarTac	Nokia 1610	Qualcomm QCP2700	Ericsson A1228d

2000	2001	2002	2003	2004	2005
Palm Treo 600	Motorola V60c	Motorola V770	Sony Ericsson T616	Motorola RAZRv3	Sony Ericsson W810i

2006	2007	2008		2010	Today
AT&T 8525	AT&T 8925	Blackberry 8830	BlackBerry Bold 9700	Apple iPhone 3G	Apple iPhone 5

mHealth: health care delivery and treatment

- ## In the U.S.
  - ### Adolescents
    - 75% have a mobile telephone
    - 50% get first telephone at 12-13 yrs.
  - ### Adults
    - 85% have a mobile telephone
    - 35% have a smartphone

- ## ~ 5 billion mobile subscribers worldwide
  - 2/3 are in developing countries
- ## ~90% of the world has wireless network

Digital Entry Dietary Records

iPhone: >1200 apps

Average price: $2.39

All iPhone Apps for "diet"
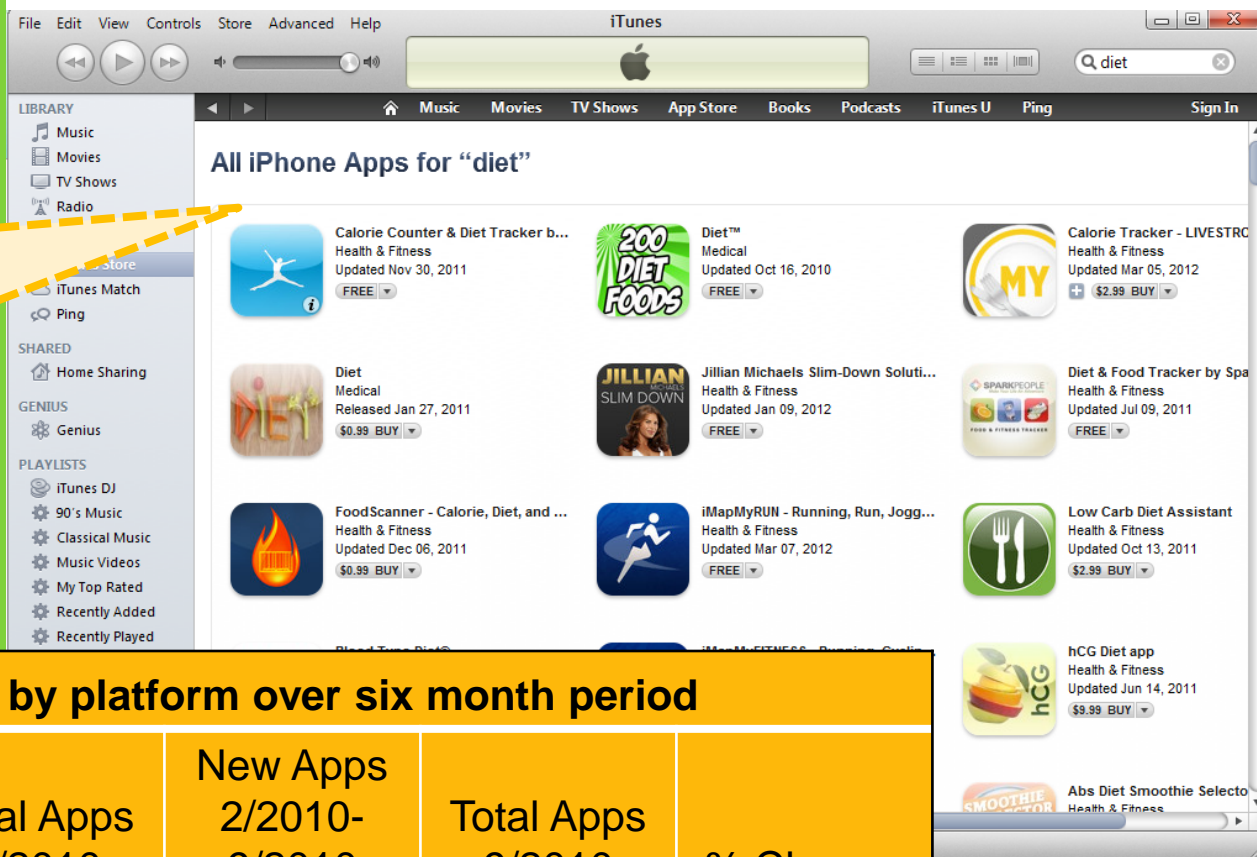
Growth of health apps by platform over six month period				
Platform	Total Apps 2/2010	New Apps 2/2010-9/2010	Total Apps 9/2010	% Change
Apple	4276	2860	7136	↑ 67
Google Android	505	791	1296	↑ 157
BlackBerry	140	198	338	↑141

mobihealthnews. 2010 report.
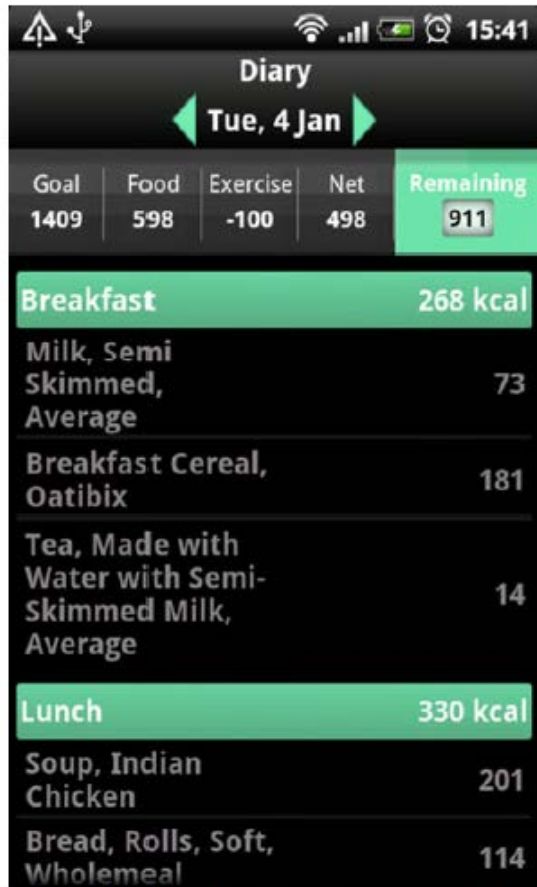
My Meal Mate

Fig. 1. Screen capture of the food diary entry page of My Meal Mate. (A colour version of this figure can be found online at www.journals. cambridge.org/bjn)
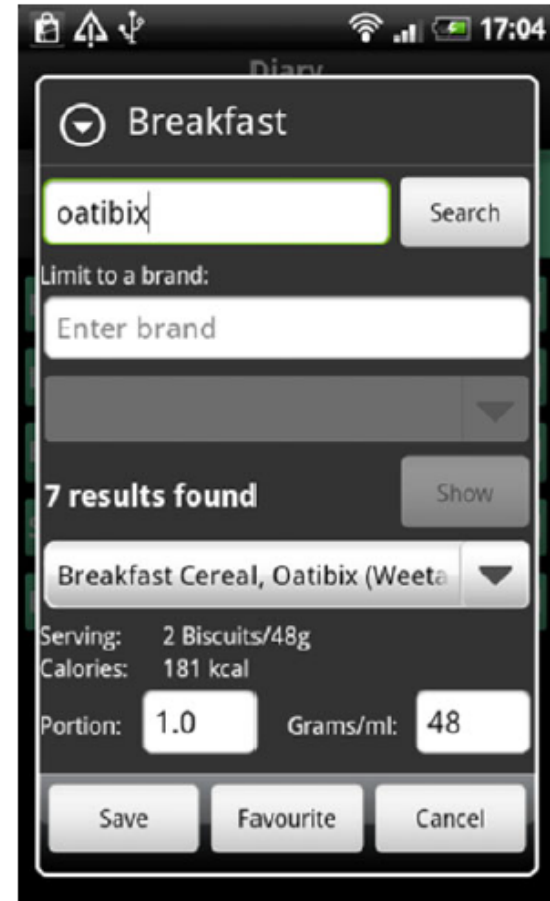
Fig. 2. Screen capture of the search page for finding a food to add to the diary. (A colour version of this figure can be found online at www.journals. cambridge.org/bjn)

Carter MC et al, Brit J Nutr 2013

Image-based dietary assessment

Sample of methods in development	Focus of process

Remote Food Photography Method
    Martin CK et al Brit J Nutr 2009
 	
A Unified Sensor System
    Sun M et al J Am Diet Assoc. 2010
	Trained Analyst

Image Diet Day Arab L and Winter A J Am Diet Assoc. 2010	Participant

Food Intake Visualization & Voice Recognizer
    Weiss R et al J Am Diet Assoc. 2010
 	
Mobile telephone food record (mpFR)
    Boushey CJ et al Euro J Clin Nutr 2009
 	
Diet Data Recorder System (DDRS)
    Shang J et al Multimedia on Mobile Devices 2012
	Automation w/ some user confirmation

Rubrics for image-assisted records or recalls
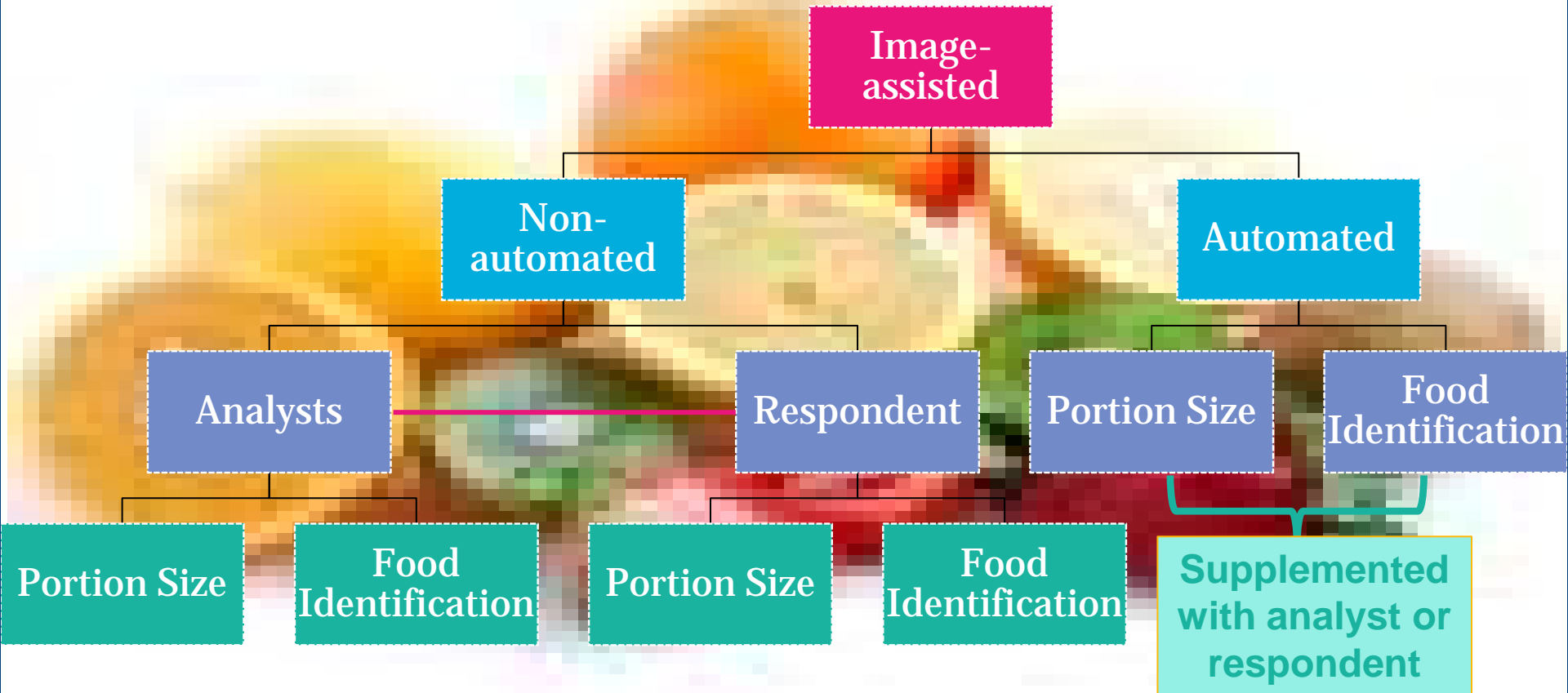
Martin CK. Br J Nutr 2009; Weiss R. J Am Diet Assoc 2010; Sun M. J Am Diet Assoc 2010; Six BL. J Am Diet Assoc 2010; Arab L. EB2010; Matthiessen TB. EB 2010.

Mobile Telephone Food Record (mpFR) System

Image(s) + Metadata

(Geolocation, Time, Barcode, Contextual Info)

- Food Label Type
- Segmented Image
- Machine Learning
- Context Processing

Client

Server

Wi-Fi/3G/4G Network

1

2

3

Volume Estimation

Review

4

6

Communication Layer

Web Server

- Labeled Images With Food Type (e.g., Milk, Toast, Eggs) **+**

TADA Databases

I-TADA

T-FNDDS

E-TADA

5

Wi-Fi/3G/4G Network

User Confirmation

7

Research community

Internet

TADA
technology assisted
dietary assessment

UNIVERSITY OF HAWAI'I
CANCER CENTER

PURDUE
UNIVERSITY

Zhu F et al. IEEE J Sel Top Signal Process 2010.

mpFR Instructions

1. ALL food and beverages
2. Fiducial Marker

Six *et al, J Am Diet Assoc.* 2010

TADA mobile application

- Mobile Telephone Food Record (mpFR)
  - Record Eating Events
    - Capture a series of before/after image pairs
    - Barcode reader
  - Review Meal
    - Review food items in images
    - Confirm and adjust food identification
    - Barcode Reader
  - Alternative Method
    - Manage eating events when food images are not captured
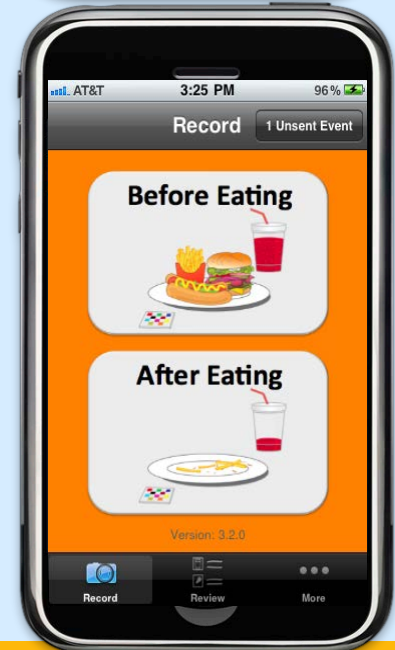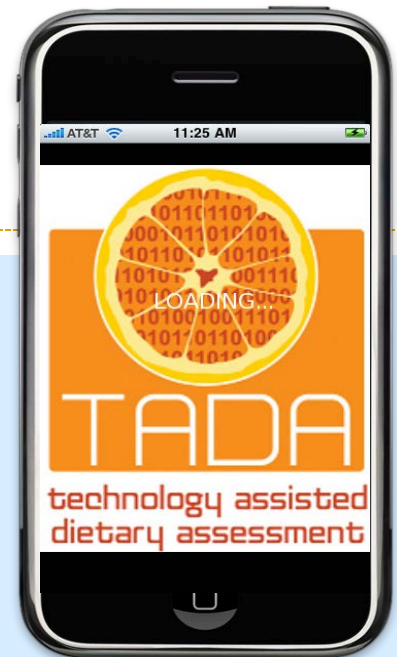
Mobile Food Intake Visualization and Voice Recognizer (FIVR)

PI: Rick Weiss, Viocare, Inc.

- User captures food records using video/images & voice using a mobile phone
- FIVR automatically identifies foods and portion sizes to reduce participant burden
- 3D structure analysis used to calculate volume/portion size from images of multiple angles
- Image recognition is used to match foods to library of foods using color, texture, shape
- FIVR calculates nutrient and food intake of consumed food
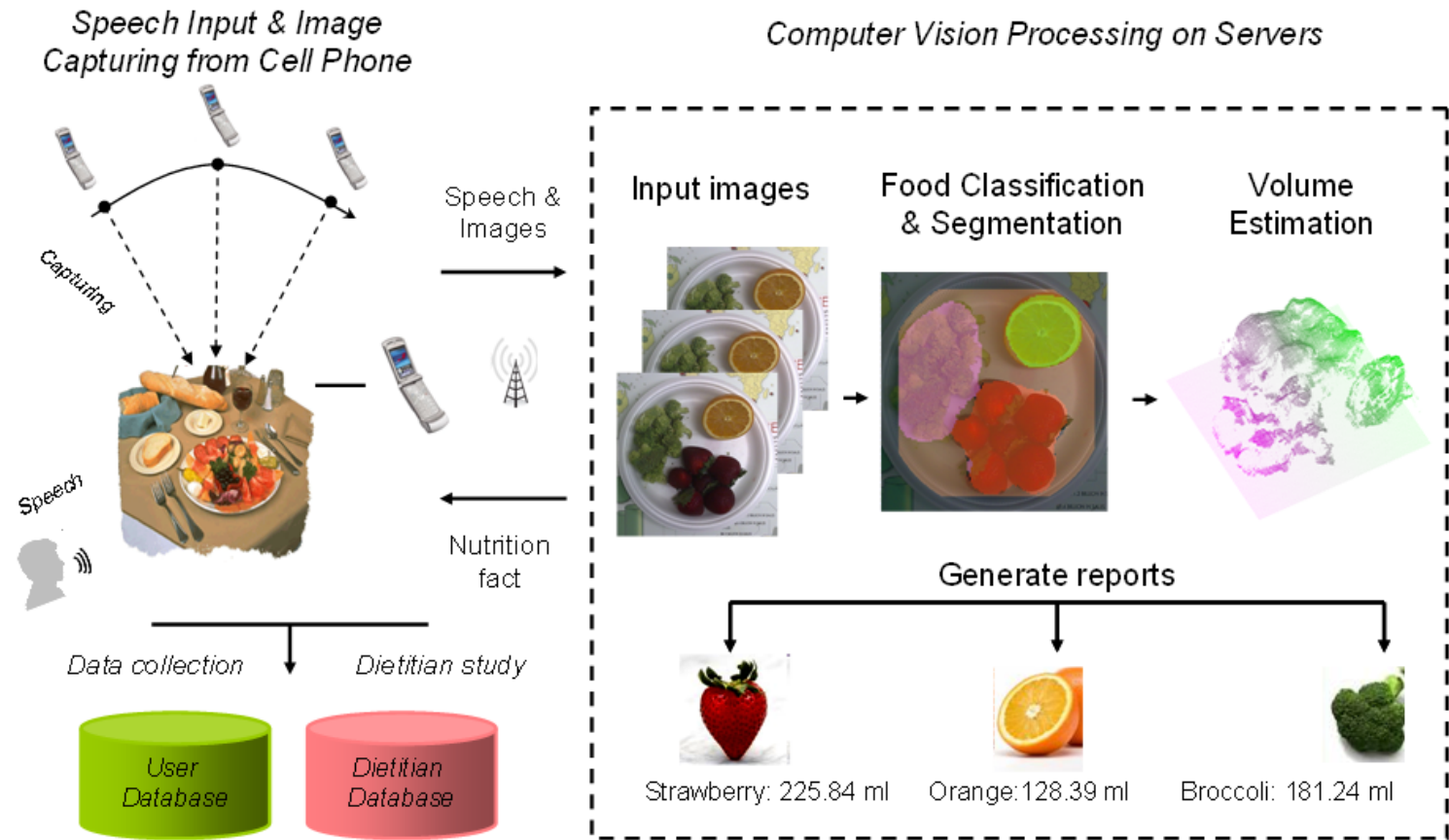
eButton for Diet and Physical Activity Assessment
PI: Mingui Sun, University of Pittsburgh

Concept: Subject wears an eButton which has an array of sensors to collect food and physical activity data every 2-4 seconds. The data are then uploaded and analyzed for energy intake and expenditure.
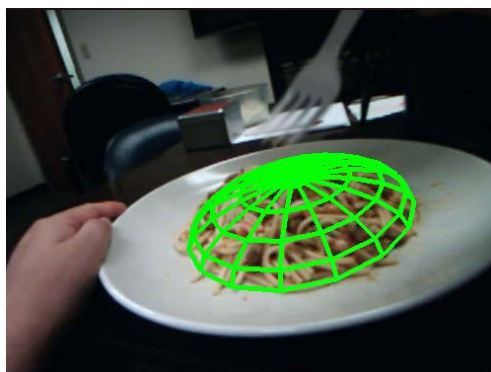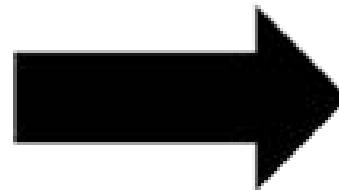

The plate diameter is used as a size reference. Food volume is measured using a wire mesh.

Image features and GPS/motion data are used for automatic physical activity recognition

Text messaging intervention group participants receive ongoing motivational messages

Text Message sent to participant

Mobile Friendly Web page

Text messaging intervention group participants receive ongoing motivational messages

Text Message sent to participant

Mobile Friendly Web page

Click on link in text

- Theoretical frameworks

Evaluation model for mobile applications

Usability
learnability,
efficiency of use, errors
and satisfaction

Utility
adherence,
persistence,
attrition

Features
social components, expert
feedback, reminders,
educational content

Adoption
acceptance,
preference

Outcomes
weight loss metrics,
behavioral change,
improved dietary
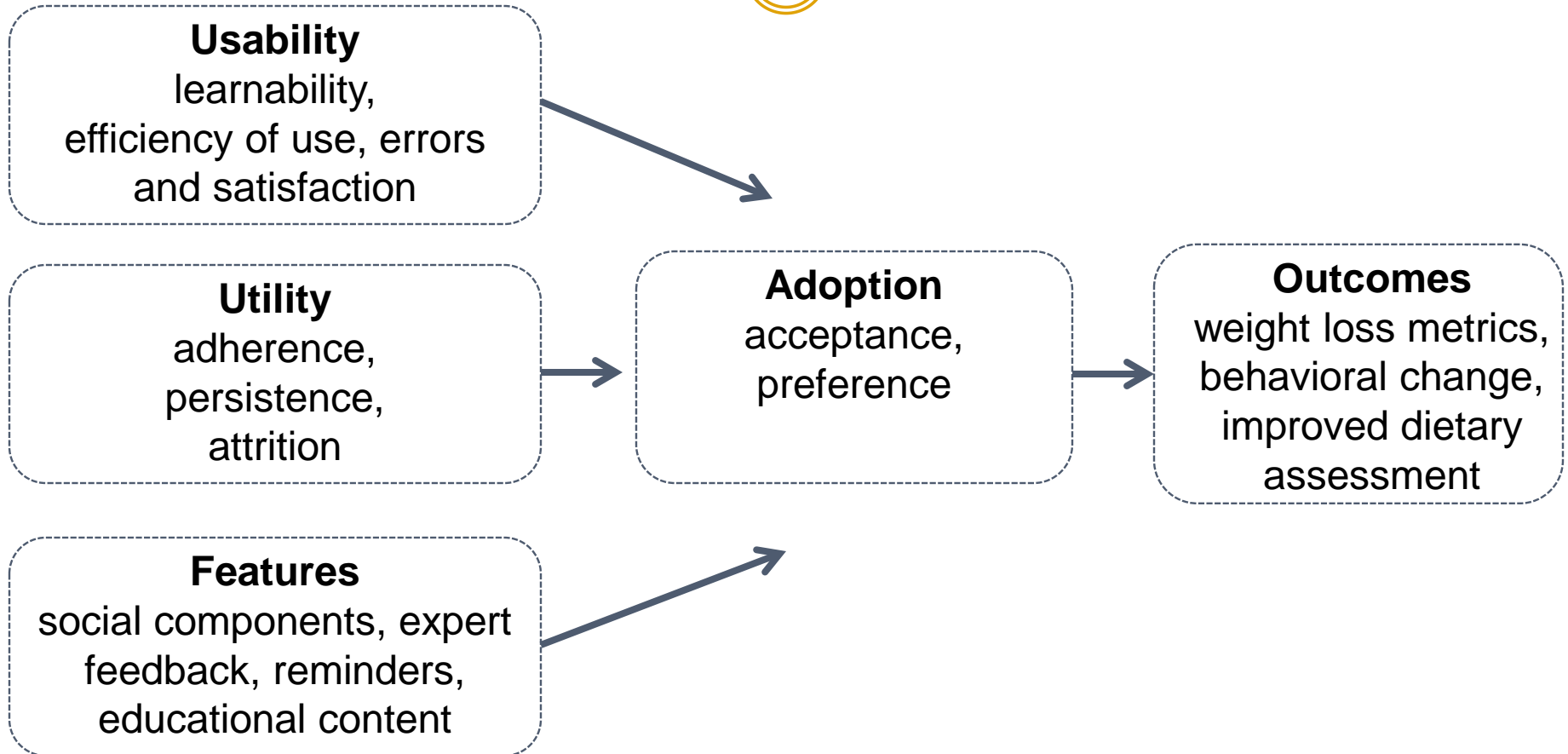assessment

Adapted from Dohan et al. AISeL 2011

Table 1 Summary of intervention content self-assessed by participants at baseline and at completion of the intervention

Ate more or less	Substitutions
Ate more:	**Switching to**
Servings of fruit and/or vegetables	Low energy/diet drinks or waters
Variety of fruits and vegetables	Lower-alcohol or non-alcoholic drinks
Adding more vegetables or salad to meals	Healthier options when eating out
	More alcohol free days every week
Ate/drank less:	
Sugary drinks (e.g. fizzy drinks, sports drinks or cordial)	
Confectionary (e.g. chocolate, lollies, cakes, sweet biscuits)	
Sugary foods (e.g. lollies, sugar in drinks)	
Fatty foods (e.g. pies, pastries)	
Alcohol	
Fast food	

Theoretical framework:
The tailored intervention will be based on self-determination theory and informed by motivational interviewing.

- Theoretical frameworks

- Collaborate with an electrical and/or computer engineer

Tips for using mobile devices in research/practice

- Theoretical frameworks
- Collaborate with an electrical and/or computer engineer
- Learn and use terminology

Examples of terminology

Lay Term	Professional Term
Photo or photograph	Image or digital image (or even picture)
Photography	Capture an image, take an image (or even take a picture)
Cell phone	Mobile telephone
	Mobile device, e.g., iPod
WiFi, Bluetooth	WiFi, Bluetooth

Tips for using mobile devices in research/practice

- Theoretical frameworks
- Collaborate with an electrical and/or computer engineer
- Learn and use terminology
- Cost & mechanics

Cost & Mechanics

- **Mobile telephone**
  - Data service plans
    - Purchase phones
    - Device cost
    - Monthly voice cost
    - Data cost
    - Text cost

  $41.49/phone

  +$5.00/phone

  - Distribute and return, or
  - Give telephone to participants

- **Mobile devices, such as an Apple iPod**
  - No service plan
  - Device cost
    - $275/device +
    - $25/protectors =
    - $300 total/device

Many Thanks

PI: Carol Boushey, PhD, MPH, RD

At Purdue University
Department of Nutrition Science
TusaRebecca Schap, PhD, MS, RD
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Bethany Daughtery, MS, RD
Elisa Bastian, MS
YuJin Lee
Ashley Chambers

Curtin University of Technology, Perth, Western Australia
Deb Kerr, PhD

Department of Agricultural & Biological Engineering
Martin Okos, PhD
Shivangi Kelkar
Scott Stella

At Purdue University
School of Electrical & Computer Engineering
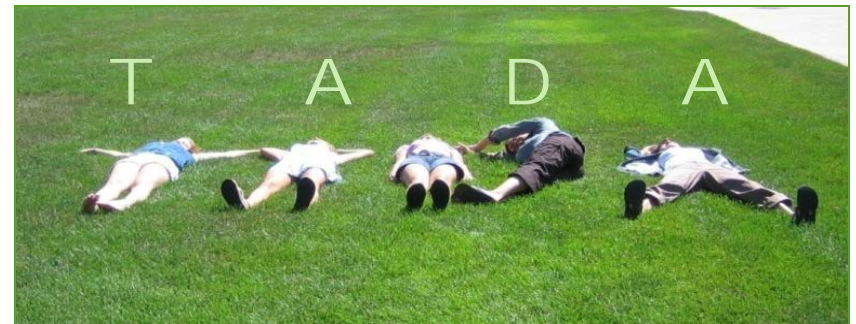Edward Delp, PhD
David Ebert, PhD
Nitin Khanna, PhD
Marc Bosch
Junghoon Chae
Ye He
Fengqing Zhu
Xu Chang
Ziad Ahmad