MT-Diet : Automated Smartphone based Diet Assessment with Infrared Images

Junghyo Lee (Speaker), Ayan Banerjee, and Sandeep K. S. Gupta

iMPACT Lab, CIDSE, Arizona Sate University, Tempe, AZ

{jlee375, abanerj3, Sandeep.Gupta}@asu.edu

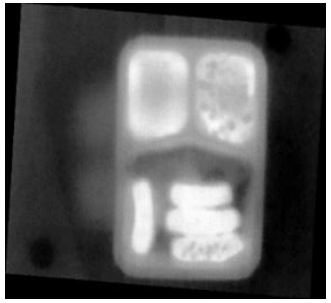
PerCom pervasive computing 2016

Diet

- American Medical Association in 2013
  - Recognized obesity as a disease officially [1]
- What is the effective method to treat and prevent the obesity?
- Existing Diet Monitoring and Problems
  - Self-monitoring
    - Low adherence, underreporting, and recall error
  - Smartphone camera based monitoring (State-of-the-art)
    - User inconvenience
      - Segment multiple foods to each single food
      - Select a food location in the image (Rectangle)
    - Fairly low food type identification accuracy (63%)

MT-Diet

- **MT-Diet**: Automated Smartphone based Diet Assessment System using ***Cyber-Physical Dynamics***
- Thermal Interaction of a food plate with the environment



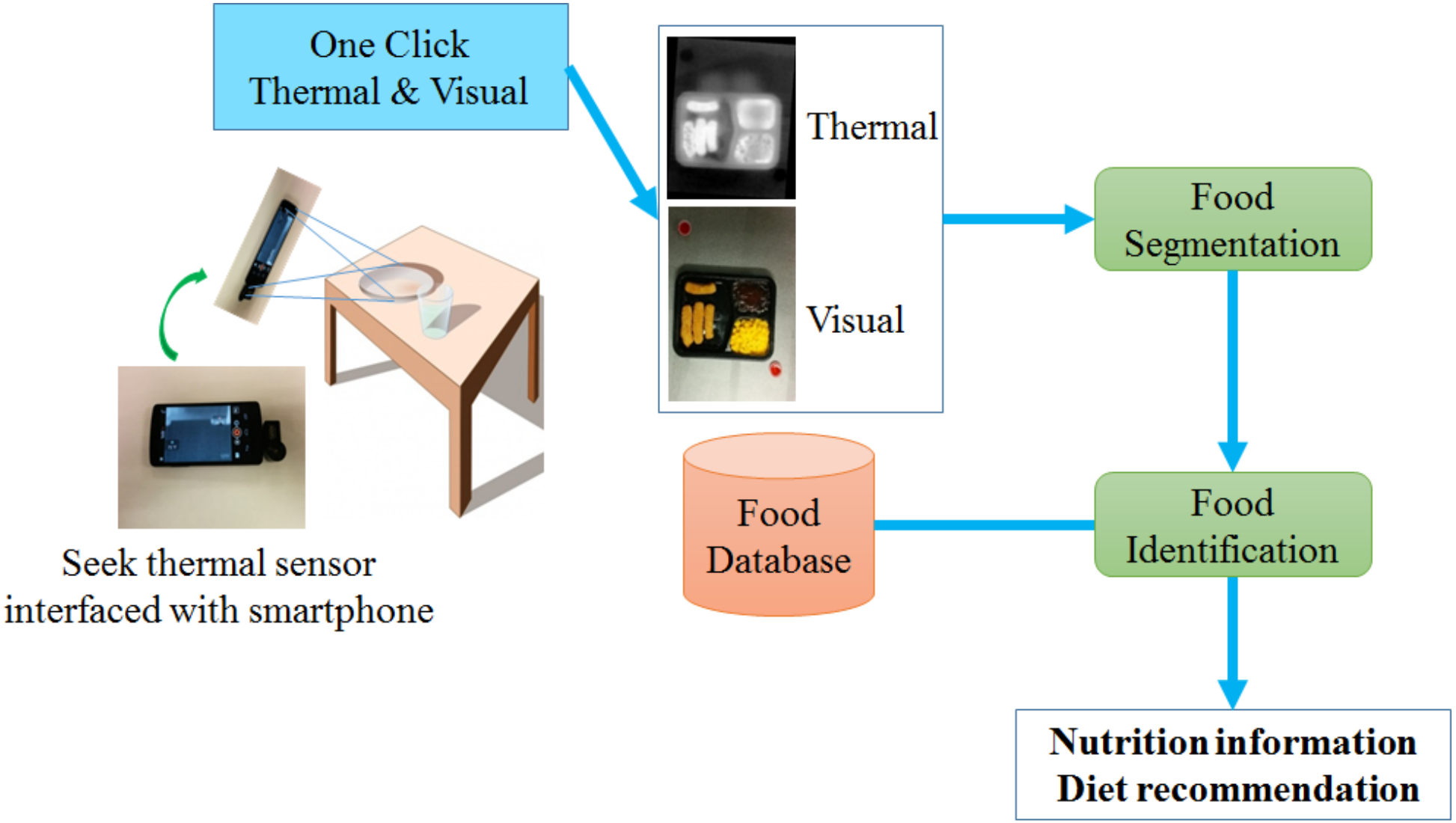
$$\frac{T_f - T_A}{T_i^f - T_A} = \exp\left(\frac{-hAt}{m_f C_p^f}\right), \qquad \frac{T_p - T_A}{T_i^p - T_A} = \exp\left(\frac{-hAt}{m_p C_p^p}\right)$$

$$\boldsymbol{If\ T_i^f \gg T_i^p,\ then\ T_f \gg T_p,\ for\ at\ least\ t > 10\ mins}$$

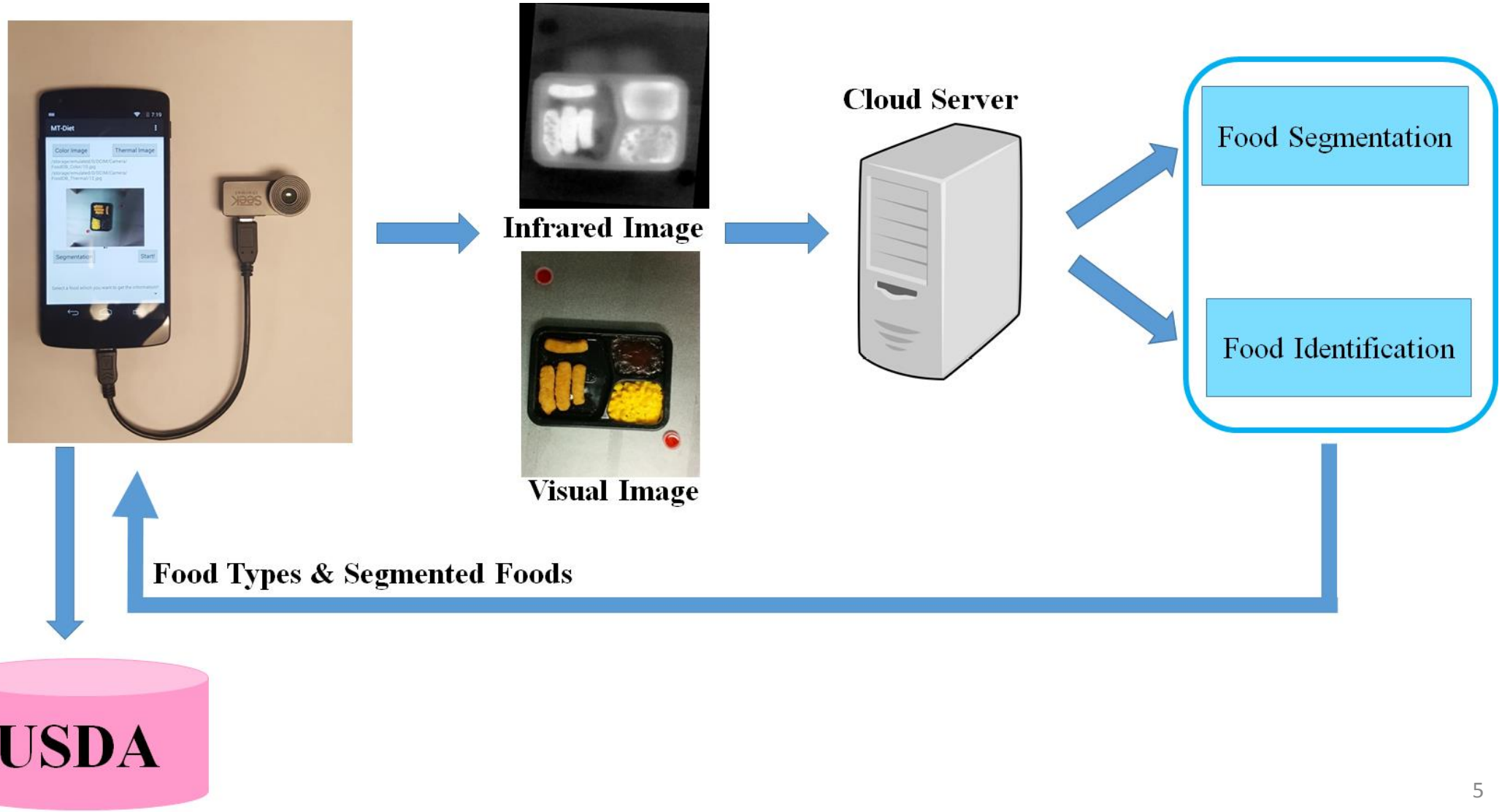
T_f- Temperature of food item at time t, T_i^f- initial food temperature, m_f - mass of food item.
T_p- Temperature of food item at time t, T_i^p- initial food temperature, m_p- mass of plate.
T_A- Ambient temperature, h - heat transfer coefficient, A- area of food item, C_p^f- specific heat of food, C_p^p- specific heat of plate.

- Contributions: Fuse Thermal and Visual Spectra
  - Thermal and Color image correct each other
- Results
  - Segment multiple foods to each single food automatically
  - High accuracy of identifying types of food (88.93%)
    - State-of-art systems have accuracy at most 63%

Overview

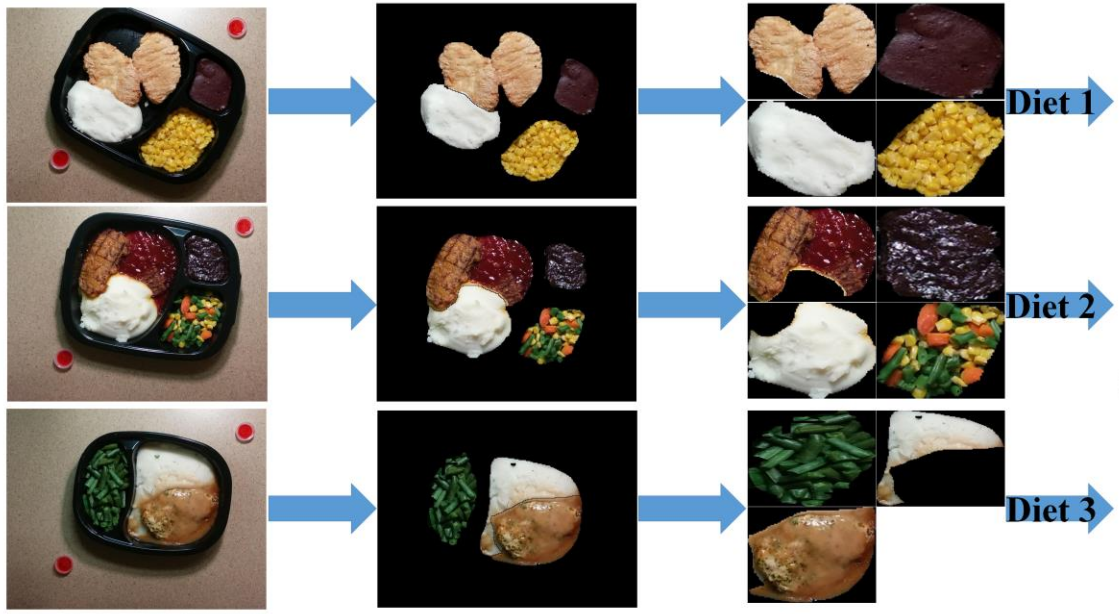

One Click
Thermal & Visual
Thermal
Visual
Food
Segmentation
Food
Database
Food
Identification
Nutrition information
Diet recommendation
Seek thermal sensor
interfaced with smartphone

System Model



Usability

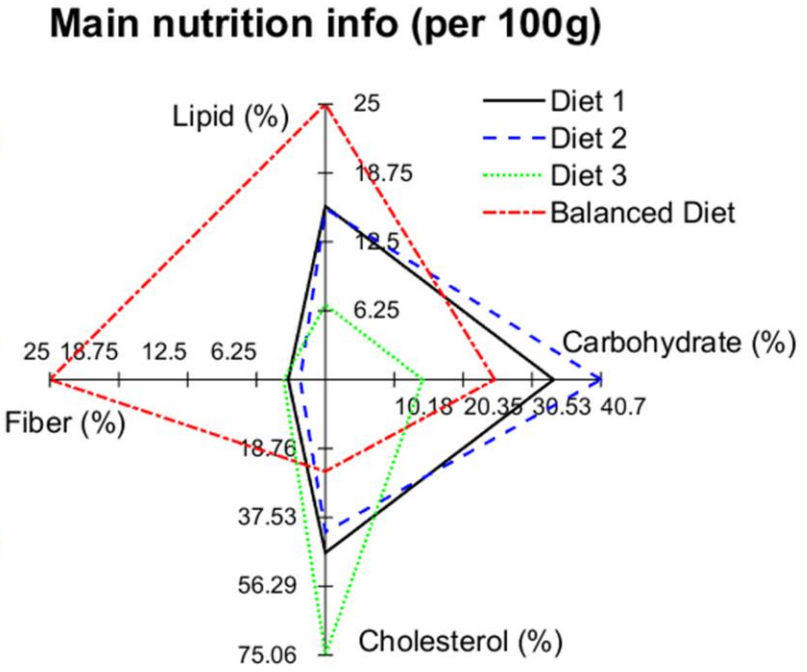
- Balanced diet recommendation
  - Assume the plate has uniform depth
  - Ratio of the surface area multiplied by the density of the food item



Calibrated & Cropped Image

Background & Plate Removed Image

Segmented Images & Identify Food Type



Comparing with Balanced Diet (Carbohydrate, Lipid, Fiber, Cholesterol)

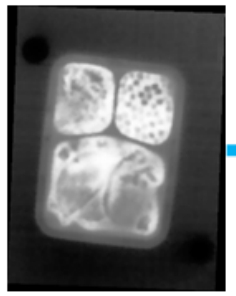
Diet Monitoring

- **Food Segmentation**
- **Food Identification**

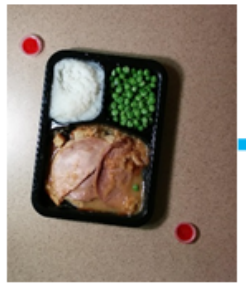
Food Recognition

- Intake Amount
- Calorie Estimation
- Dietary Feedback
- Behavior Control

MT-Diet



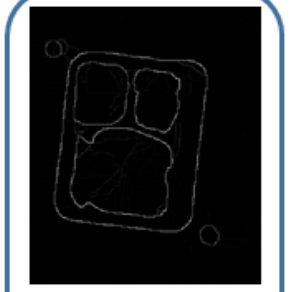
Infrared Image



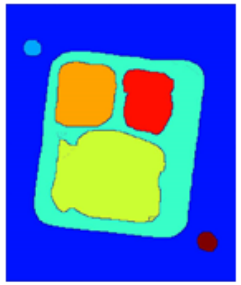
Visual Image

Dynamic Thermal Thresholding (DTT)

Hierarchical Image Segmentation (HIS)



Contour Image



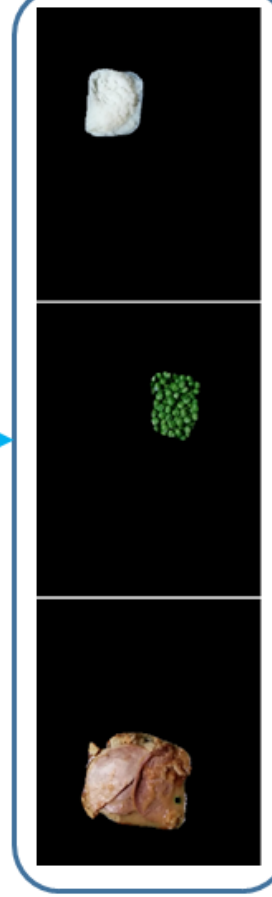
Segmented Image

Combine

Find Region of Food (ROF)

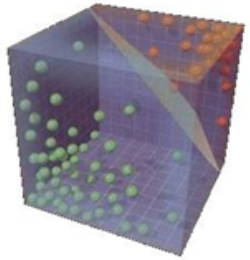
Multiple Foods Segmentation

Segmented Single Foods



Features
1. Color
2. Histogram of Oriented Gradient
3. Texture

Food Database



Support Vector Machine Classifier

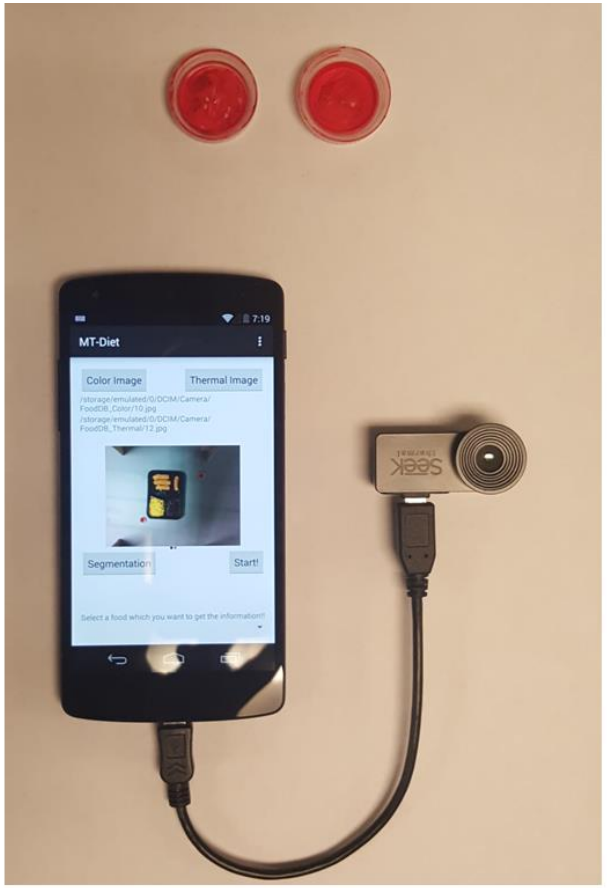
Mashed potato
Green bean
Turkey

Image Acquisition

Food Segmentation

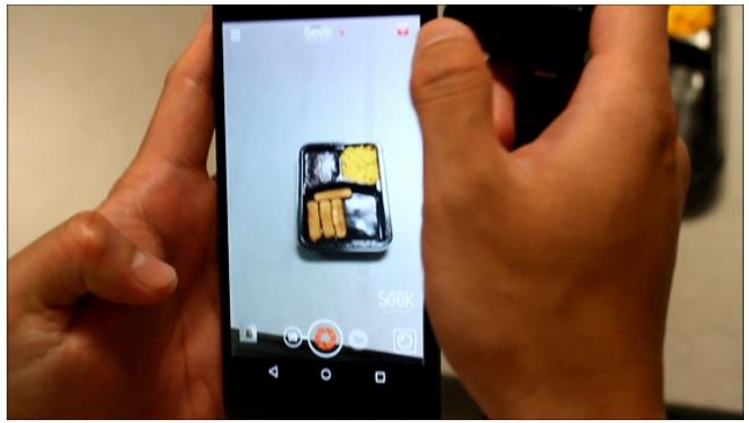
Food Identification

Image Acquisition



Equipment of MT-Diet Prototype

Usage of Thermal Camera


Usage of Smartphone Camera

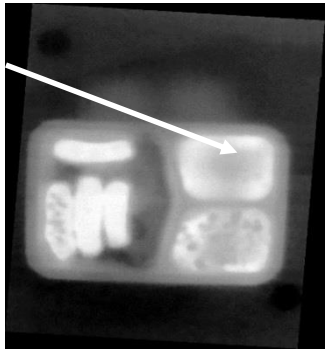
- Prototype of MT-Diet
  - Nexus 5
  - Seek thermal sensor
  - Micro USB wire
- Thermal Image
  - Seek thermal sensor interfaced with the Nexus 5
- Color Image
  - From Built-in Nexus 5 Camera

Food Segmentation

Challenges for Image Based Food Segmentation (1)

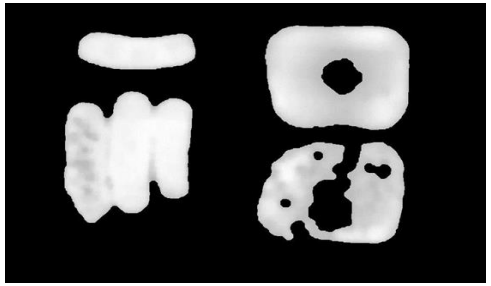
- Visual spectra may not have defined boundaries
  - Thermal boundaries more significant

Better Contrast in Infrared Spectra

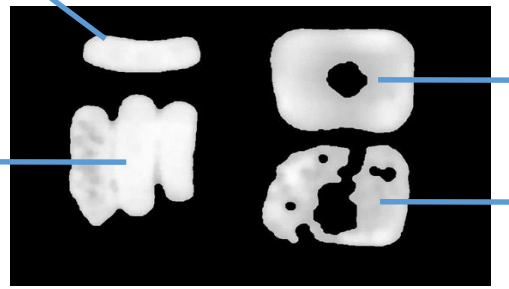


DTT Output

Food Item Location



8 – connected component labeling [2]

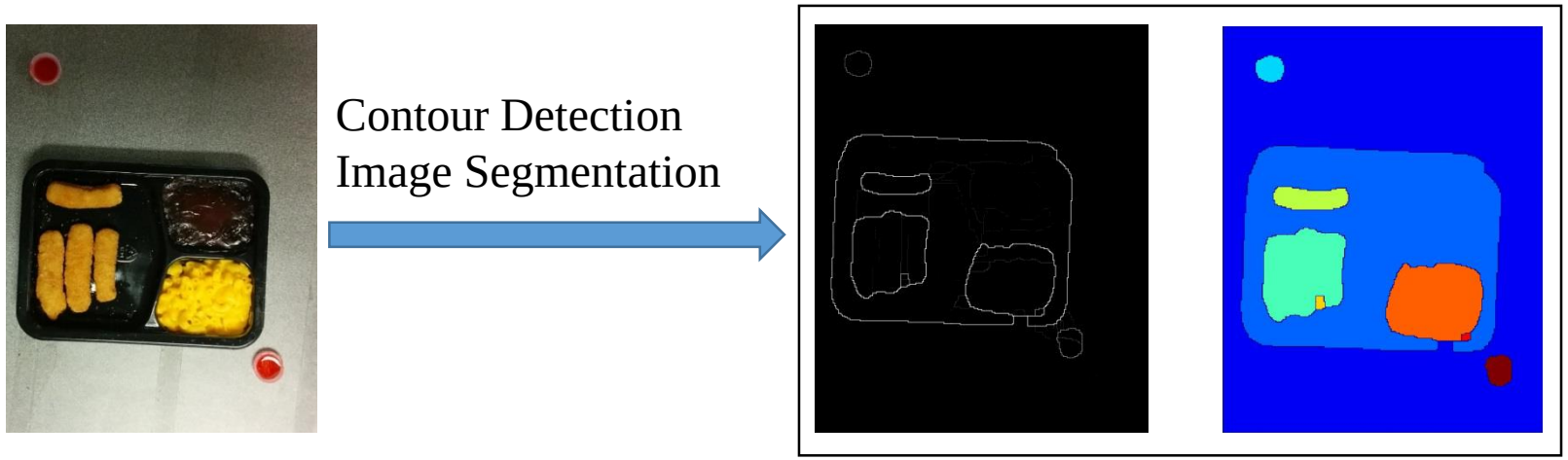


  - Thermal signatures are not stable

Dynamic Thermal Thresholding (DTT)

Challenges for Image Based Food Segmentation (2)

- Color (Gradient) and Texture are important features for identification
- Food items of same color as plate may be lost in visual spectra
- Fusion of visual and infrared spectra

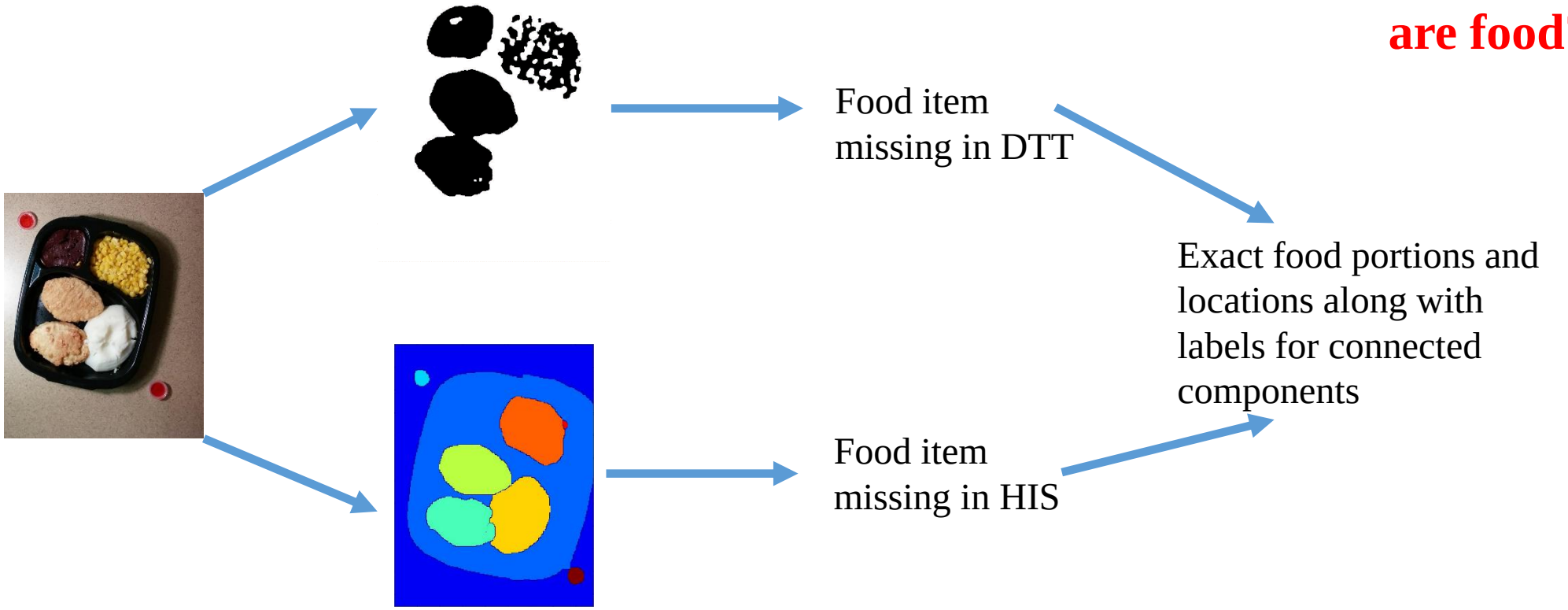


Hierarchical Image Segmentation (HIS) [3]

Challenges for Image Based Food Segmentation (3)

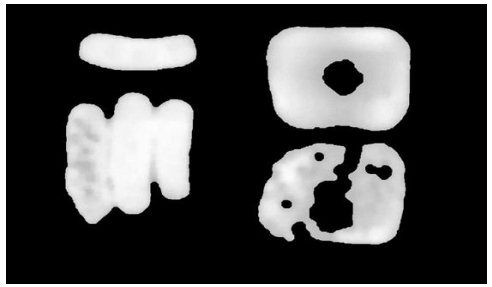
- Food items not heated enough get deleted in DTT output
  - Color image can recognize the food

Which portions are food?



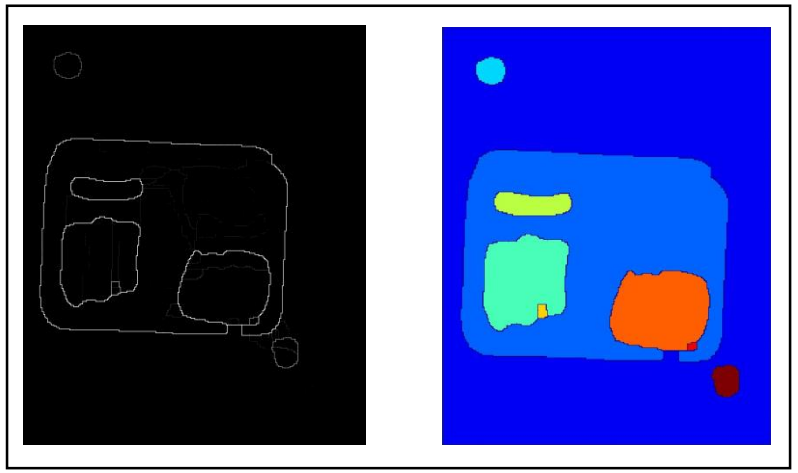
Label Matching

- Identifies unique food items in both **infrared** and **visual spectra**

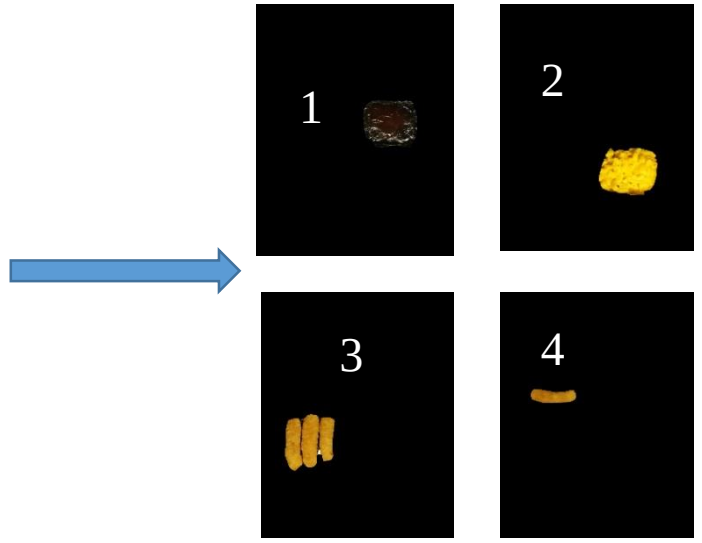


DTT output with food labels

+



Contour and Image segments from visual spectra



- Remove plate portions that are connected to food items with Grabcut [4]

Food Identification

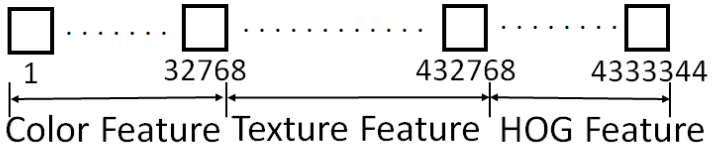
Feature Set

- Objective
  - Classify the food type using SVM with kernels
- Feature Extraction
  - Color feature
    - RGB histogram: 32 histogram bins of each color channel
  - Histogram of Oriented Gradient feature [4]
    - 16 windows and 36 bins of oriented gradients of the each windows
  - Texture feature [5]
    - Resized food image (400 X 400), 5 scales, 8 orientations, 4 by 4 down sampling

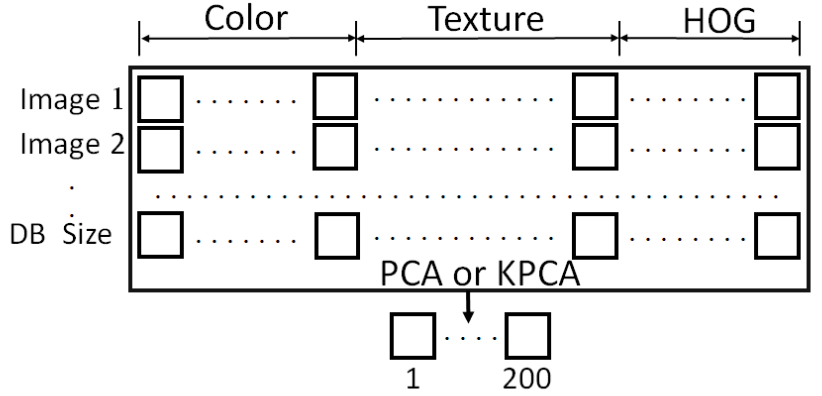
Feature Fusion Methods

- Feature Fusion
  - Three fusion methods
  - Method of Dimensionality Reduction
    - Kernel Principal Component Analysis
    - Principal Component Analysis

① Concatenation

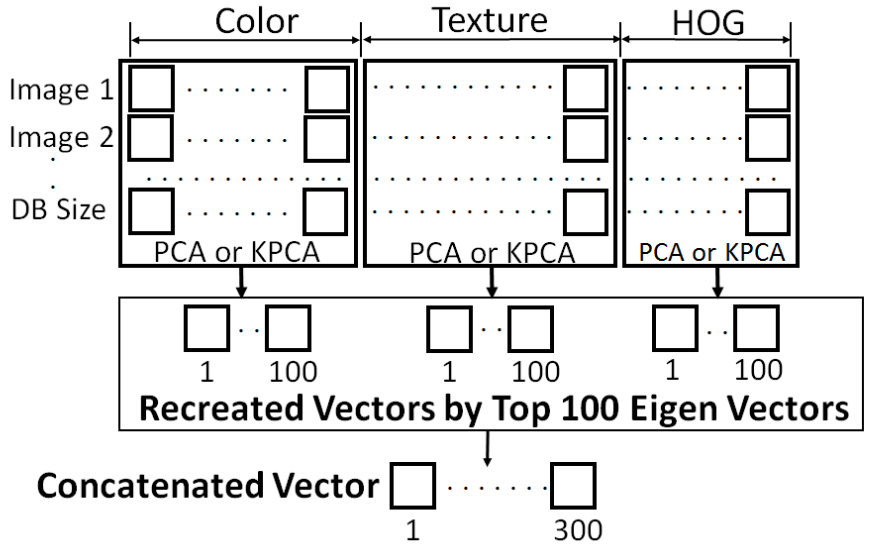


② Dimension Reduction of ①



Recreated Vector by Top 200 Eigen Vectors

③ Dimension Reduction of Each Feature



Experimental Results

Segmentation Result

20 Food Types
in practice

Execution Time of Food Segmentation

- Execution time (s) of food segmentation using i7 processor

	Min	Median	Max	Sum	Avg	STD
HIS	89.08	92.89	97.50	7403.9	92.55	1.66
DTT	2.83	3.13	3.9	256.12	3.2	0.24
ROF	0.39	0.78	1.01	62.77	0.78	0.09
Grabcut	2.4	14.24	41.15	1138.97	13.48	7.63
Total	95.51	111.59	145	8911.79	111.46	7.71

Food Identification Result

Feature	Best Methods (Reduction, Kernel, Fusion)	Accuracy(%)	Execution(s)	Feature Size
Texture	KPCA, RBF	45.08	5.13	100
HOG	PCA, RBF	63.11	0.35	100
RGB	KPCA, Sigmoid	88.11	0.57	100
HOG & Texture	KPCA, RBF, 3	59.43	5.13	200
HOG & RGB	KPCA, RBF, 3	88.93	0.7	200
RGB & Texture	KPCA, RBF, 3	88.93	5.62	200
All	KPCA, RBF, 3	87.7	5.43	300

Conclusion

- **MT-Diet : Automatic diet monitoring system** that interfaces thermal
- High accuracy of automated food identification (88.93%)
- User-friendly diet monitoring system application
  - Only one task (Click a button)
  - Expected the promoted healthy eating habits

Even If your diet log is the empty…..

References

[1] [Online]. Available: http://www.ama-assn.org/ama/pub/news/news/2013/2013-06-18-new-ama-policies-annual-meeting.page

[2] H. Samet and M. Tamminen (1988). "Efficient Component Labeling of Images of Arbitrary Dimension Represented by Linear Bintrees". *IEEE Transactions on Pattern Analysis and Machine Intelligence* (TIEEE Trans. Pattern Anal. Mach. Intell.) **10** (4): 579. doi:10.1109/34.3918.

[3] P. Arbelaez, M. Maire, C. Fowlkes, and J. Malik, "Contour detection and hierarchical image segmentation," Pattern Analysis and Machine Intelligence, IEEE Transactions on, vol. 33, no. 5, pp. 898–916, 2011.

[4] Rother, C., Kolmogorov, V., & Blake, A. (2004, August). Grabcut: Interactive foreground extraction using iterated graph cuts. In *ACM transactions on graphics (TOG)* (Vol. 23, No. 3, pp. 309-314). ACM.

[5] N. Dalal and B. Triggs, "Histograms of oriented gradients for human detection," in Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on, vol. 1. IEEE, 2005, pp. 886–893.

[6] M. Haghighat, S. Zonouz, and M. Abdel-Mottaleb, "Identification using encrypted biometrics," in Computer Analysis of Images and Patterns. Springer, 2013, pp. 440–448.

Acknowledgment

Dr. Petteri Nurmi for shepherding out paper

Dr. Meg Bruening for her insights on diet monitoring

NSF IIS 1116385

NIBIB EB019202

GPSA for supporting the conference travel grant

Questions