Background & Objective
◆ Health care on foods is important to avoid obesity and diseases.
◆ Object recognition techniques is growing greatly these days.

An automatic food advisory system become possible now!!

A food recognition engine for a food advisory system is needed.

Requirements for a food recognition engine
◆ Can recognize many kinds of food (>50) with high classification rate.
◆ Can output a result within 30 seconds.

Multiple Kernel Learning (MKL)
◆ Achieved highest performance for Caltech-101/256 (89.6% / 60.6%)
[Varma et al. ICCV2007]
◆ Integrate many kinds of image features.

We propose a food recognition engine using MKL in this paper.

Method
◆ Feature fusion by Multiple Kernel Learning (MKL)
  - Bag-of-features (BOF) : 6 kinds
  - Gabor features : 2 kinds
  - Color histogram : 1 kind

◆ Multiple Kernel Learning
  - Is an extension of a SVM
  - Can handle "a combined kernel" which is a linear combination of kernels.
  - Can estimate kernel weights and SVM model parameters simultaneously.
  - Can integrate features by assigning one feature to one kernel.

Features (9 Kinds)
◆ Bag-of-features (BoF) (local pattern)
  (1) Sample points in three ways
  (2) Describe local patterns around the sampled points with SIFT [Lowe 2004]
  (3) Generate codebooks by k-means (size of a codebook: k=1000, 2000)
  (4) Convert images into BoF vectors by voting to nearest codewords
  - Totally generate six kinds of BoF vectors (1000, 2000)×(DoG, rand, grid)
◆ Color histograms (color) 64dim.
◆ Gabor features (texture)
  - 6 directions × 4 frequencies
  - Extract from 3x3 and 4x4 grids
  - Totally 216dim. & 384dim.

Experiments
◆ 50 category classification by one-vs-rest (5-fold cv)
◆ Classification rate for 50 categories.

<table>
<thead>
<tr>
<th>Image features</th>
<th>Classification rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>color</td>
<td>38.18%</td>
</tr>
<tr>
<td>BoF(dog,2000)</td>
<td>25.52%</td>
</tr>
<tr>
<td>BoF(grid,2000)</td>
<td>27.48%</td>
</tr>
<tr>
<td>BoF(grid,1000)</td>
<td>26.19%</td>
</tr>
<tr>
<td>BoF(random,2000)</td>
<td>27.66%</td>
</tr>
<tr>
<td>BoF(random,1000)</td>
<td>28.42%</td>
</tr>
<tr>
<td>BoF(random,2000)</td>
<td>29.70%</td>
</tr>
<tr>
<td>BoF(random,3000)</td>
<td>31.90%</td>
</tr>
<tr>
<td>BoF(random,5000)</td>
<td>34.64%</td>
</tr>
</tbody>
</table>

MKL (after fusion) 61.34%

◆ The best five and the worst five

<table>
<thead>
<tr>
<th>Category</th>
<th>Recall</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>mino soup</td>
<td>99%</td>
<td>4</td>
</tr>
<tr>
<td>sukiyaki</td>
<td>94%</td>
<td>2</td>
</tr>
<tr>
<td>nuts</td>
<td>93%</td>
<td>4</td>
</tr>
<tr>
<td>potato</td>
<td>95%</td>
<td>2</td>
</tr>
<tr>
<td>omelette</td>
<td>97%</td>
<td>3</td>
</tr>
</tbody>
</table>

Weights estimated by MKL

Classification rate within top N

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Classification rate: 61.34%

Ranking (7)

30.08%

Ranking (3)

28.08%

50.94%

Some ill-conditioned cellular photos
out of focus, after eating half, taken partly

Conclusions
◆ Propose a food recognition engine with MKL-based future fusion
  - Achieved 61.34% classification rate
  - 80.05% when allowing three candidates

◆ Future work
  - More than 100 categories
  - More features (e.g. shape context, PHoG)
  - Other features (e.g. date/time, GPS info.)
  - Implement a food advisory system