Semantic Mapping of Natural Language Input to Database Entries via CNNs

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Motivation

America’s Rising Obesity Rate

15% 22% 31% 34%


Percent of obese Americans

The GLUTEN-FREE VEGAN

Loves Healthy Foods
Partial Solution: USDA

1,252 foods found. Click on a food name to view details.

- BBQ Chicken Breast
  - Aladdin, 1 Breast
  - 141
- Tyson Chicken Breast
  - Protein, 3.5 oz
  - 165
- Roasted Chicken Breast
  - Aladdin, 1 Each
  - 147
- Smoked Chicken Breast
  - Aladdin, 2 oz
  - 113
- Pesto Chicken Breast
  - Aladdin, 1 Each
  - 180
- Rotisserie Chicken Breast
  - Costco, 3 oz
  - 120
- Shredded Chicken Breast
  - Plain, 100 g
  - 165
- Grilled Chicken Breast
  - Aladdin, 1 Each
  - 171
- Chicken Breast Cutlets
Our Solution

Hi Mandy! I'm Lana - your personal nutritionist.

I'm here to help you log and summarize your daily nutrition.

Just let me know what you've had to eat!

I had a bowl of oatmeal and a glass of milk.

Let me take a look at that...

Snack

Breakfast: Milk, Oatmeal 440.0 CAL

Snack: Butter, Stalk 0.0 CAL

Lunch: Salad, Sandwich 421.0 CAL

421.0 Calories 21%
0.0mg Cholesterol 0%
1.6g Fiber 6%

(Matt McEachern, Karan Kashyap)
Old Approach: Simple Word Matching

I drink a glass of Tropicana orange juice

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>09206</td>
<td>Orange juice, raw</td>
</tr>
<tr>
<td>09207</td>
<td>Orange juice, canned, unsweetened</td>
</tr>
<tr>
<td>42270</td>
<td>Beverages, Orange juice drink</td>
</tr>
<tr>
<td>09209</td>
<td>Orange juice, chilled, includes from concentrate</td>
</tr>
</tbody>
</table>
Problem
New Approach: Direct Mapping to USDA

for dinner I had a bowl of \textit{chili} over \textit{rice} and an \textit{apple}

- \textit{chili} with \textit{beans} \textit{canned}
- \textit{rice} \textit{white} \textit{short-grain} \textit{cooked}
- \textit{apples} \textit{raw} \textit{with skin}
Step 1: Data Collection

Instructions

Using the images below, create a meal as if you had eaten some of the foods depicted:

- You've eaten **at least THREE** of the items in the images
- **Check the boxes** of the items you use
- Database names are provided, however, **describe the foods how you would normally say them** (i.e. Kiwifruit -> Kiwi)
- **Specify** appropriate **quantities** (i.e. a cup, a bowl, two tablespoons, one)
- **Do not just list** the food items
- **Do not add** additional items to the meal
- If the same image appears more than once, just select one. It doesn't matter which

- Oranges, Raw, All Commercial Varieties
- Corn, Sweet, Yellow, Cooked, Boiled, Drained, Without Salt
- Melons, Casaba, Raw
- Mushrooms, White, Raw
- Kiwifruit, Green, Raw
- Sweet Potato, Cooked, Baked In Skin, Flesh, Without Salt
- Carrots, Cooked, Boiled, Drained, Without Salt
- Bananas, Raw
- Strawberries, Raw
Step 1: Data Collection

- Collected 31,712 meal logs on Amazon Mechanical Turk.
Step 2: Convolutional Neural Networks (CNN)

- Yan Lecun et al: Very deep CNNs for text classification
- Yoon Kim et al: CNNs for sentence classification
- Sentence matching
  - Liang Pang et al: Text matching as image recognition
  - Baotian Hu et al: CNN architectures for matching natural language sentences
  - Wenpeng Yin et al: ABCNN: Attention-Based CNN for Modeling Sentence Pairs
Step 2: Convolutional Neural Networks (CNN)

I had a slice of toast

Matches:
1. bread, white
2. bread, wheat
3. bread, rye

...
Step 2: Convolutional Neural Networks (CNN)

Predict: 1 (Match) or 0 (Not Match)

CNN (64 filters, w=3 tokens)
Embedding (50d)
Padded Input 0 0 0 … chili with beans
USDA Food

0 0 0 … for dinner i had a bowl of chili over rice and an apple

Match?
Step 3: Predicting USDA Matches

Predicted Matches:
1. chili with beans canned
2. rice white short – grain cooked
3. apples raw with skin

for dinner I had a bowl of chili over rice and an apple
Step 3: Finite-State Transducer (FST)

Meal FST

Compose

Food FST
Step 3: Finite State Transducer (FST)

- FST decoder generates predicted USDA food matches.

Meal: I had a bowl of cereal, one egg white, and a glass of juice.

Alignment: Other Other Other Other Other Other ID8243 Other Other ID1124 ID1124 Other Other Other Other Other Other ID9233 Other

USDA Items:
- ID8243: Cereals ready-to-eat, GENERAL MILLS, HONEY NUT CLUSTERS
- ID1124: Egg, white, raw, fresh
- ID9233: Passion-fruit juice, yellow, raw
Re-training CNN with Augmented Data

• Augment data with FST-predicted aligned tokens

Training Sample 1

[chili with beans canned] USDA Food

for dinner I had a bowl of chili over rice and an apple

Full Meal Description

Training Sample 2

[chili with beans canned] USDA Food

chili

Aligned Tokens
New Model Performs Better (101 Foods)

- Recall: % of correctly predicted USDA foods

<table>
<thead>
<tr>
<th>Model</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old: CRF tagger + USDA Lookup</td>
<td>78.9%</td>
</tr>
<tr>
<td>New: CNN + FST Top-1</td>
<td>89.2%</td>
</tr>
<tr>
<td>New: CNN + FST Top-5</td>
<td>90.6%</td>
</tr>
</tbody>
</table>
Analysis: Spike Profile

- McDonald's Big Mac
- Catsup
- Bananas raw
- Fast foods cheeseburger; single regular patty with condiments

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Analysis: Nearest Neighbors

Chicken broiler or fryers breast skinless boneless meat only raw

1. Chicken broilers or fryers drumstick meat and skin cooked fried flour
2. KFC fried chicken original recipe breast meat only skin and breading removed

Cookies chocolate chip refrigerated dough baked

1. Cookies brownies commercially prepared
2. Snacks granola bars soft uncoated chocolate chip
Ongoing and Future Research

• Extend to full USDA database, as well as larger Minnesota database
• Character-based models
• User testing
• Personalized nutrition advice
• Follow-up questions