Semantic Mapping of Natural Language Input to Database Entries via CNNs

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Motivation

Partial Solution: USDA

milk

Try a new search

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

NDB No.	Description
45100704	IC, CHOCOLATE MILK STRAWS, CHO
01223	plement, milk based, Muscle Milk, pow
42131	Milk dessert, frozen, milk-fat free, chocolate
01224	Protein supplement, milk based, Muscle Milk Ligh
01244	Milk dessert bar, frozen, made from lowfat milk
11379	Potatoes, mashed, dehydrated, prepared from fla
11929	Potatoes, mashed, prepared from granules, witho
01083	Milk, lowfat, fluid, 1% milkfat, with added nonfat
01086	Milk, nonfat, fluid, with added nonfat milk solids,
01152	Milk, reduced fat, fluid, 2% milkfat, with added no

Chicken breast

Recent   Frequent   My Foods   Meals   Recipes

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
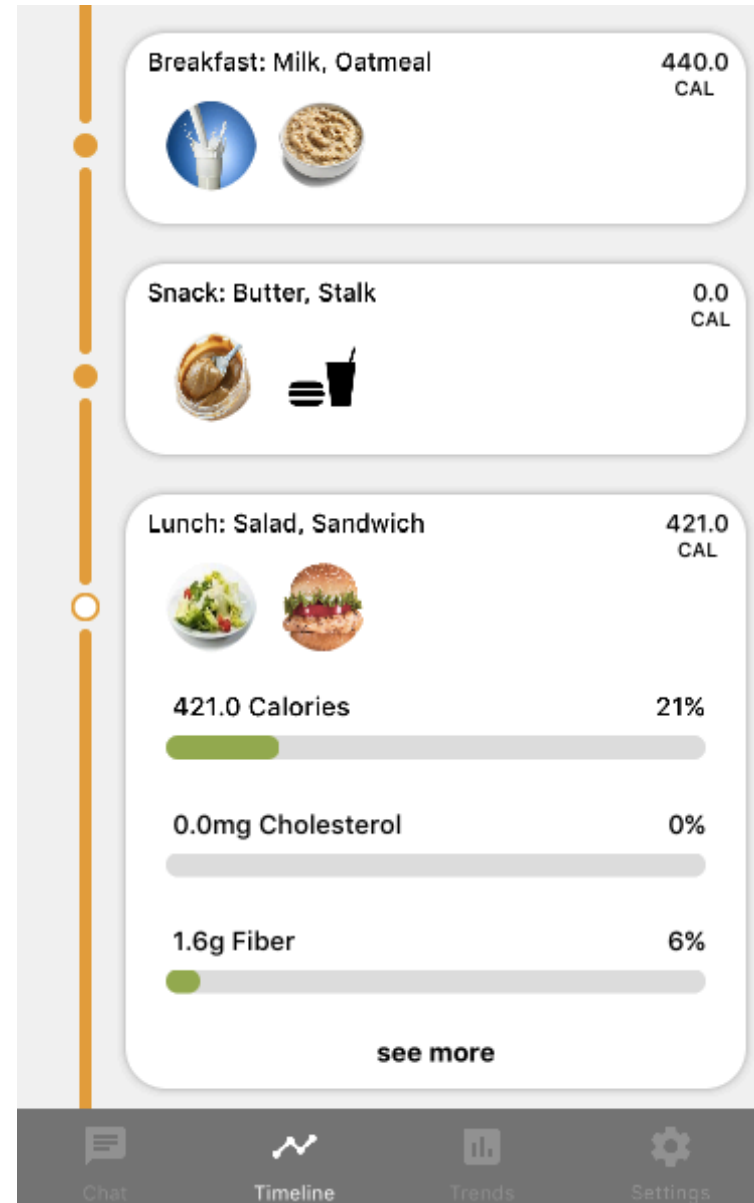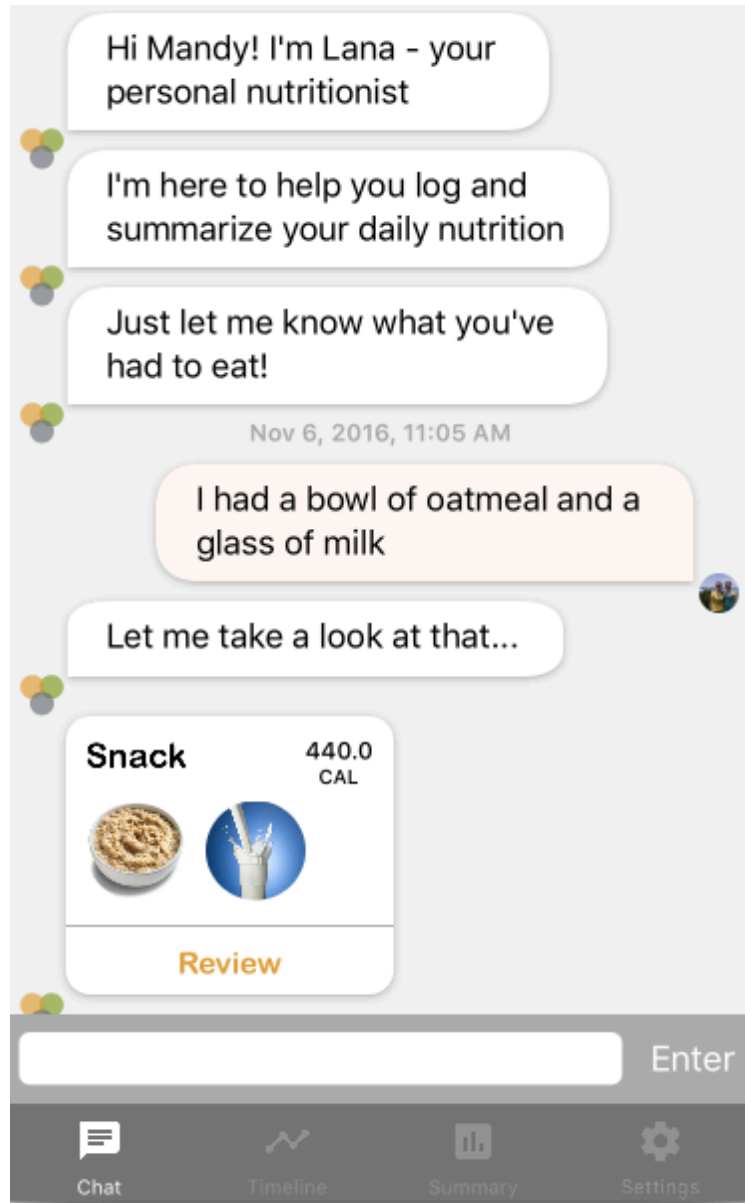
(Matt McEachern, Karan Kashyap)

Old Approach: Simple Word Matching

I drink [a glass] of [Tropicana] [orange] [juice]
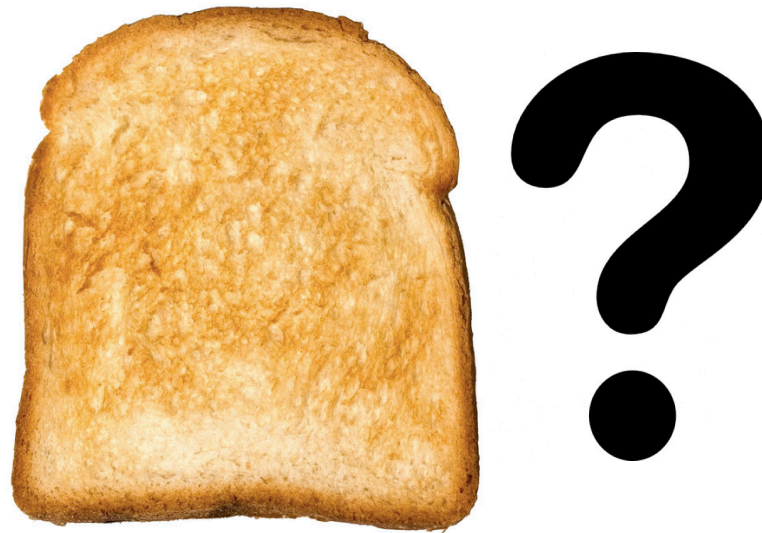
Quantity — Brand — Description — Food

[Tropicana] [orange] [juice] →

09206	Orange juice, raw
09207	Orange juice, canned, unsweetened
42270	Beverages, Orange juice drink
09209	Orange juice, chilled, includes from concentrate

Problem

New Approach: Direct Mapping to USDA

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

chili with beans canned

rice white short-grain cooked

apples raw 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

X
Oranges, Raw, All Commercial Varieties

Corn, Sweet, Yellow, Cooked, Boiled, Drained, Without Salt

X
Strawberries, Raw

Melons, Casaba, Raw

Mushrooms, White, Raw

X
Kiwifruit, Green, Raw

Sweet Potato, Cooked, Baked In Skin, Flesh, Without Salt
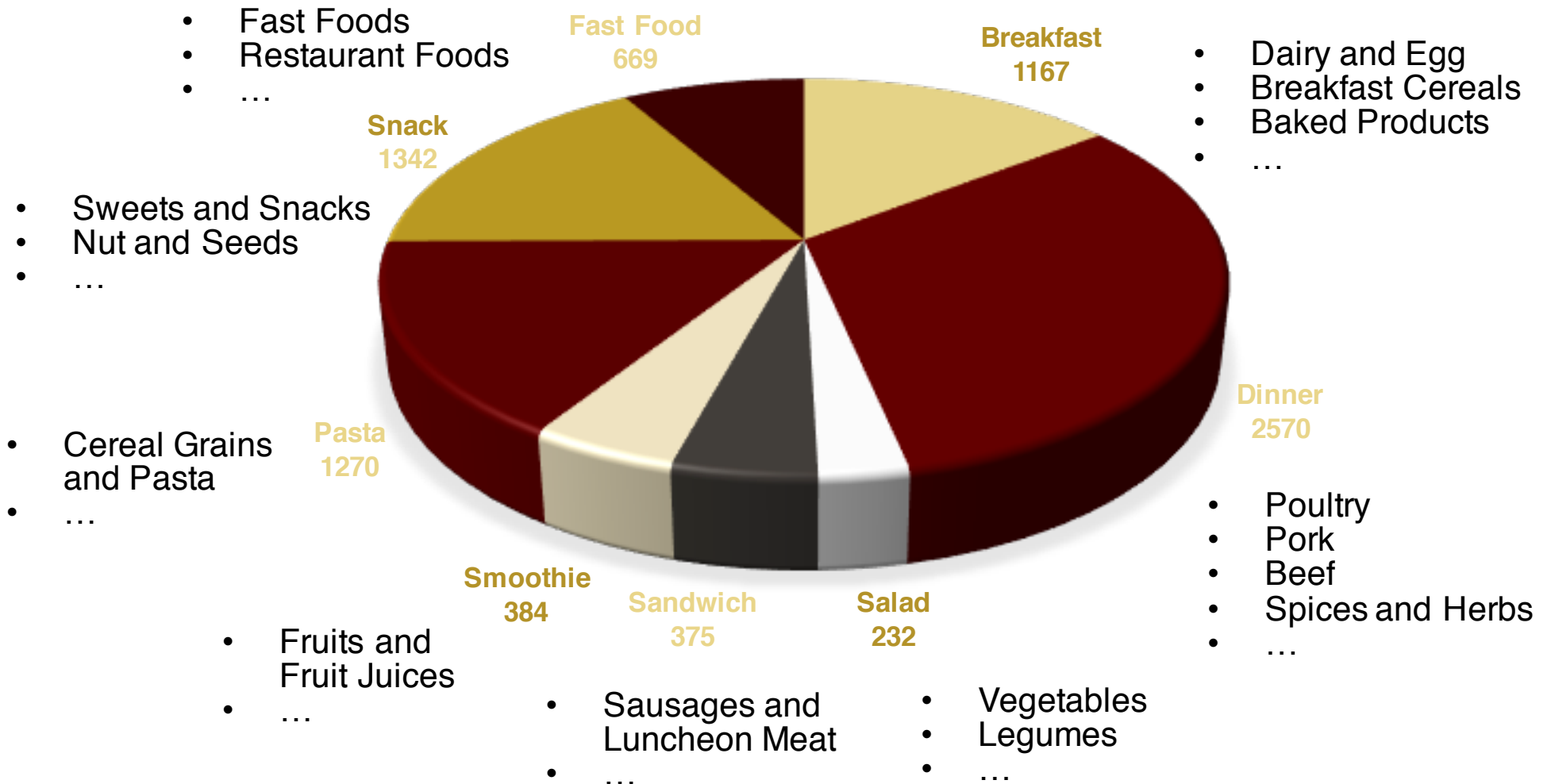
Carrots, Cooked, Boiled, Drained, Without Salt

X
Bananas, Raw

Step 1: Data Collection

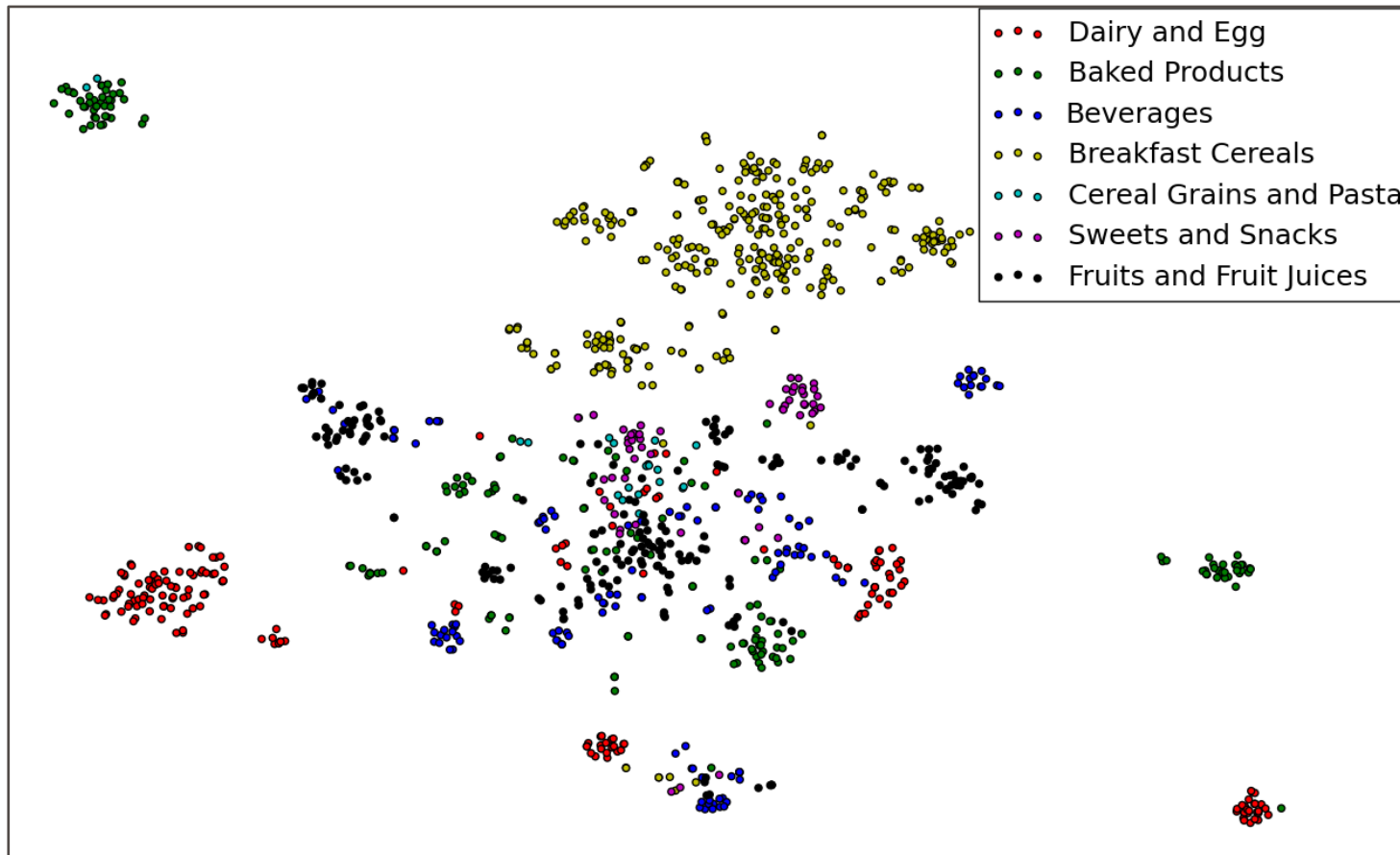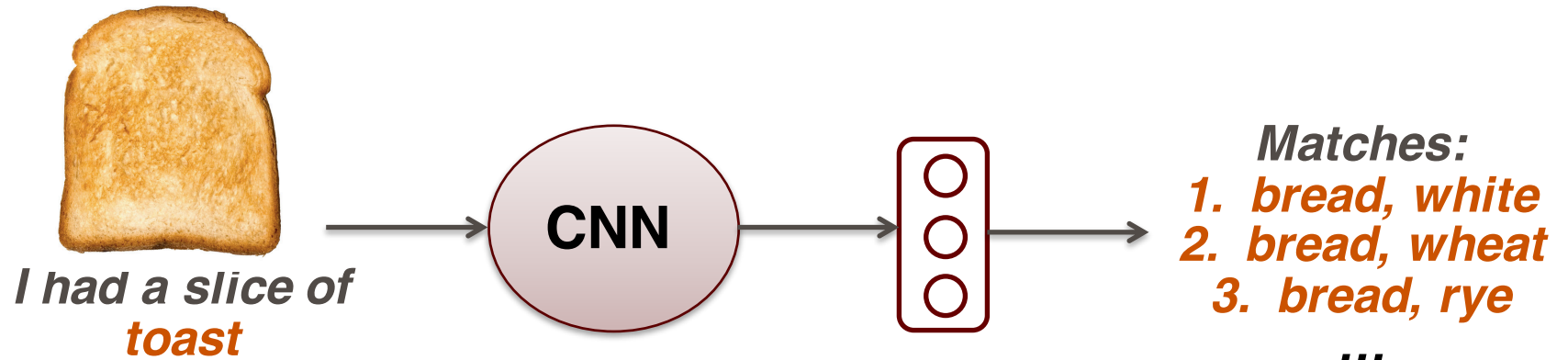- **Collected 31,712 meal logs on Amazon Mechanical Turk.**

NUMBER OF FOODS PER MEAL

- Fast Foods
- Restaurant Foods
- ...

Fast Food 669

Breakfast 1167

- Dairy and Egg
- Breakfast Cereals
- Baked Products
- ...

Snack 1342

- Sweets and Snacks
- Nut and Seeds
- ...

- Cereal Grains and Pasta
- ...

Pasta 1270

Dinner 2570

- Poultry
- Pork
- Beef
- Spices and Herbs
- ...

Smoothie 384

Sandwich 375

Salad 232

- Fruits and Fruit Juices
- ...

- Sausages and Luncheon Meat
- ...

- Vegetables
- Legumes
- ...

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**
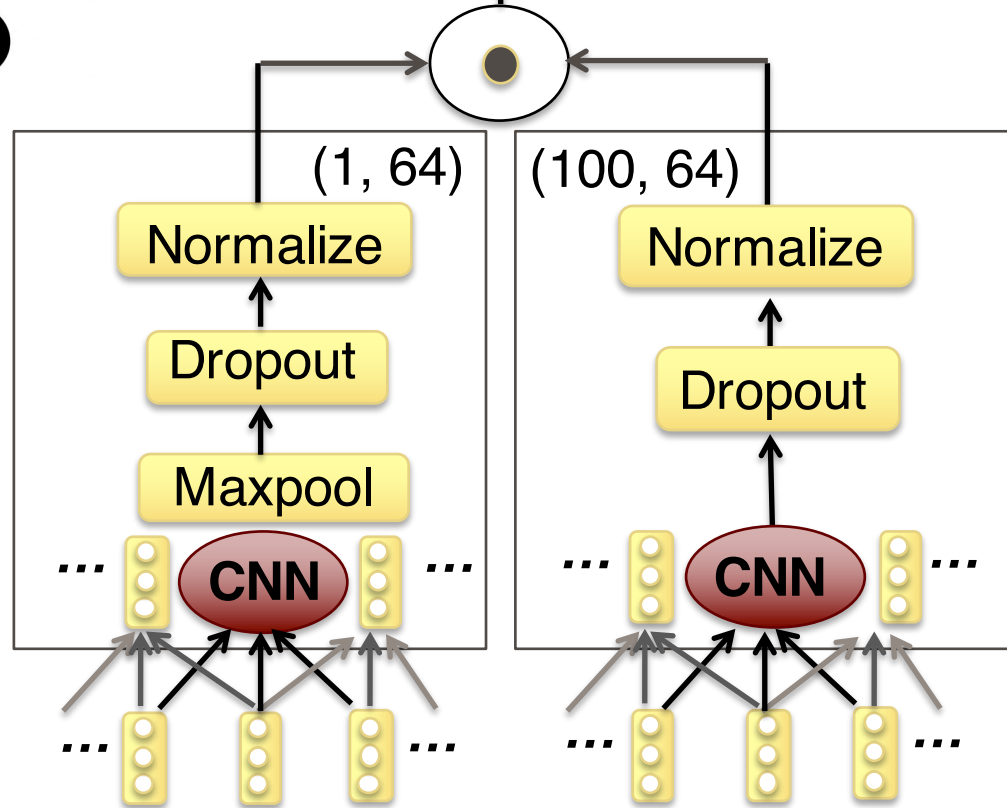
Step 2: Convolutional Neural Networks (CNN)

I had a slice of **toast**

CNN

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

- Dairy and Egg
- Baked Products
- Beverages
- Breakfast Cereals
- Cereal Grains and Pasta
- Sweets and Snacks
- Fruits and Fruit Juices

Step 2: Convolutional Neural Networks (CNN)

Sigmoid → **Predict: *1 (Match)* or *0 (Not Match)***

Meanpool

100 Dot Products

(1, 64)   (100, 64)

Normalize   Normalize

Dropout   Dropout

Maxpool

CNN (64 filters, w=3 tokens)

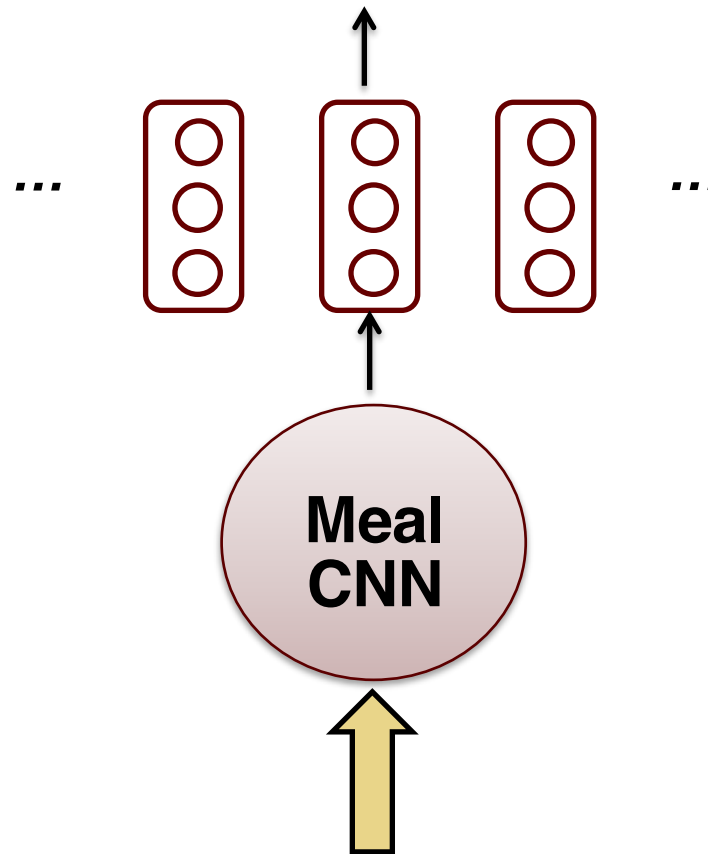CNN   CNN

Embedding (50d)

Padded Input   ***0 0 0 … chili with beans***   ***0 0 0 … for dinner i had a bowl of chili over rice and an apple***

USDA Food ⟷ Meal Description

Match?

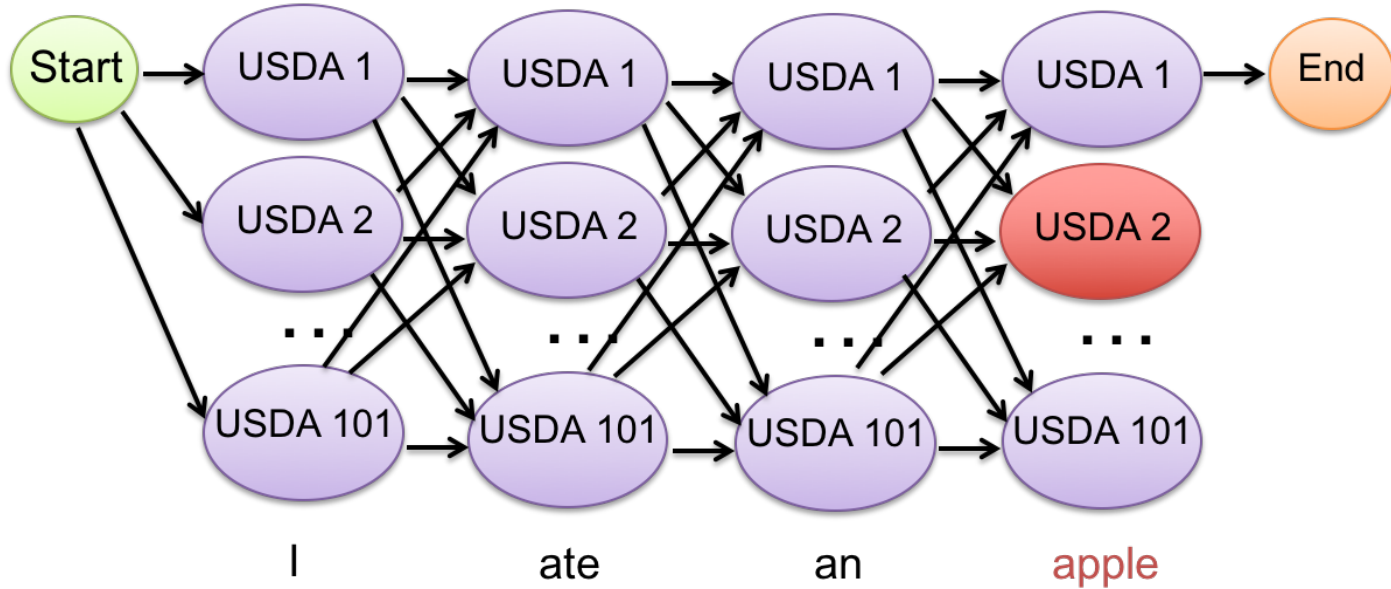# Step 3: Predicting USDA Matches

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

Meal CNN

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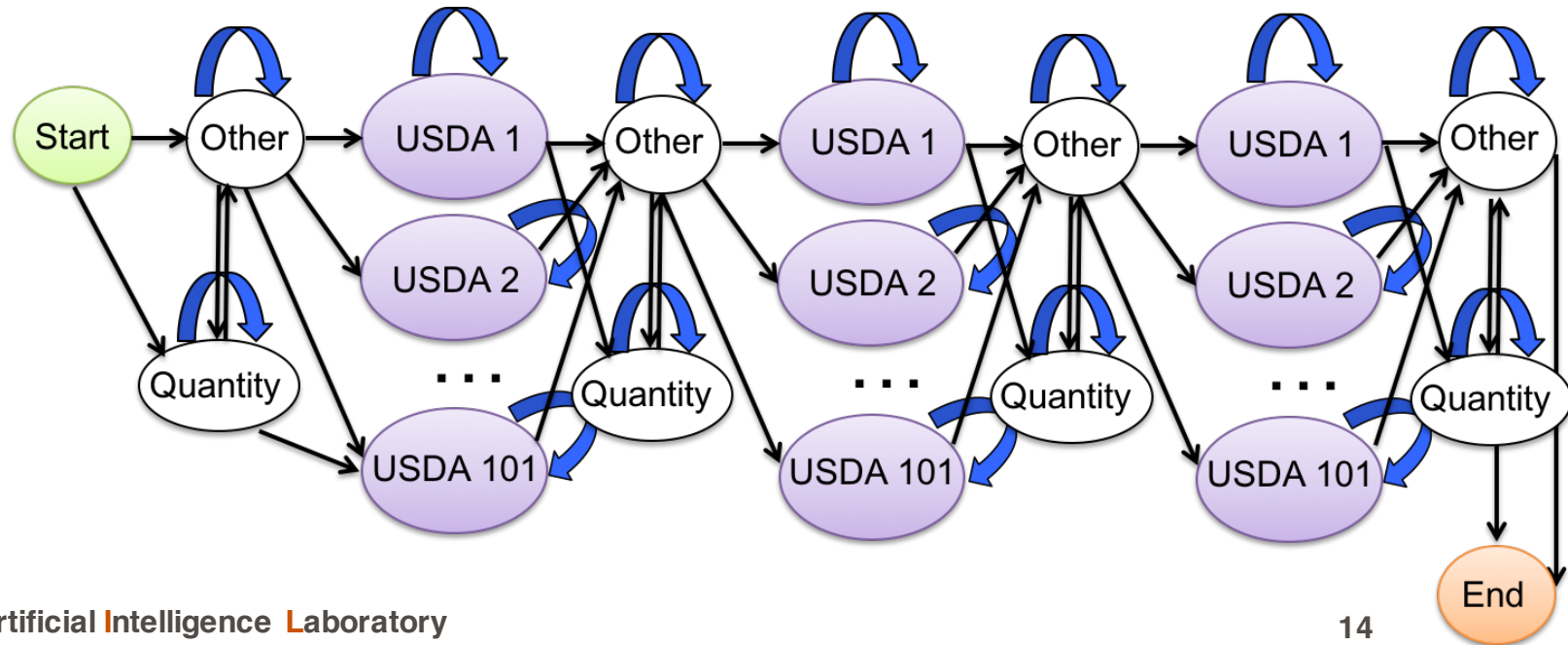
Step 3: Finite-State Transducer (FST)

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 .*

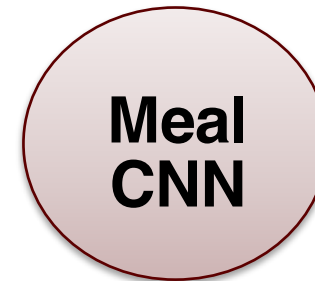Alignment: *Other Other Other Other Other ID8243 Other Other ID1124 ID1124 Other Other Other Other Other ID9233 Other*
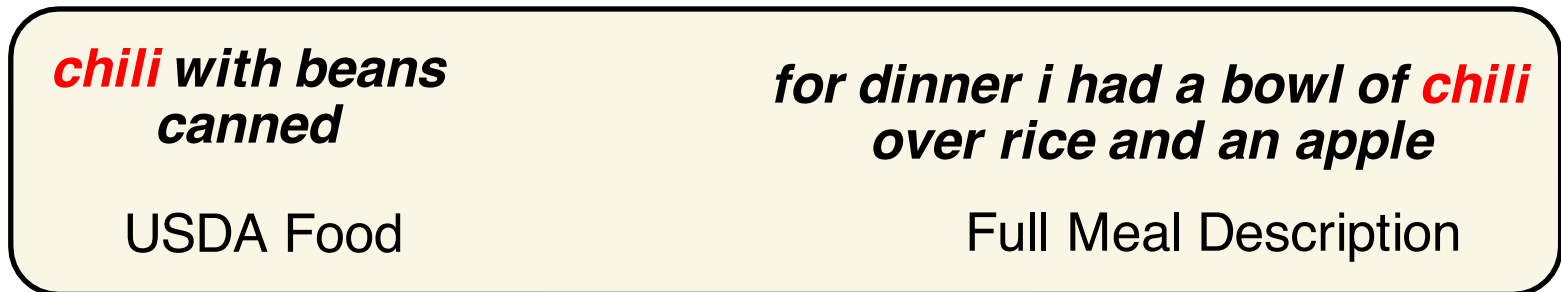
USDA Items:
- ID8243: Cereals ready-to-eat, GENERAL MILLS, HONEY NUT CLUSTERS
- ID1124: Egg, white, raw, fresh
- ID9233: Passion-fruit juice, yellow, raw

Re-training CNN with Augmented Data

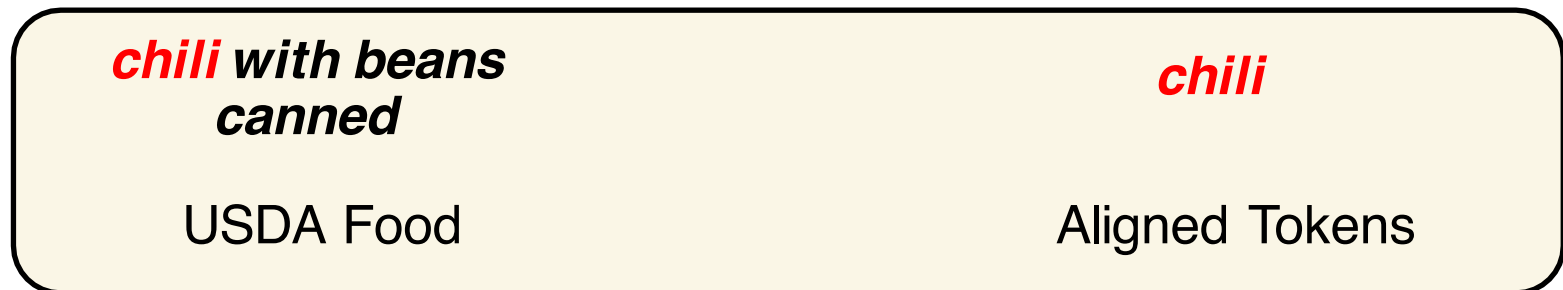- **Augment data with FST-predicted aligned tokens**

USDA CNN

Meal CNN

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
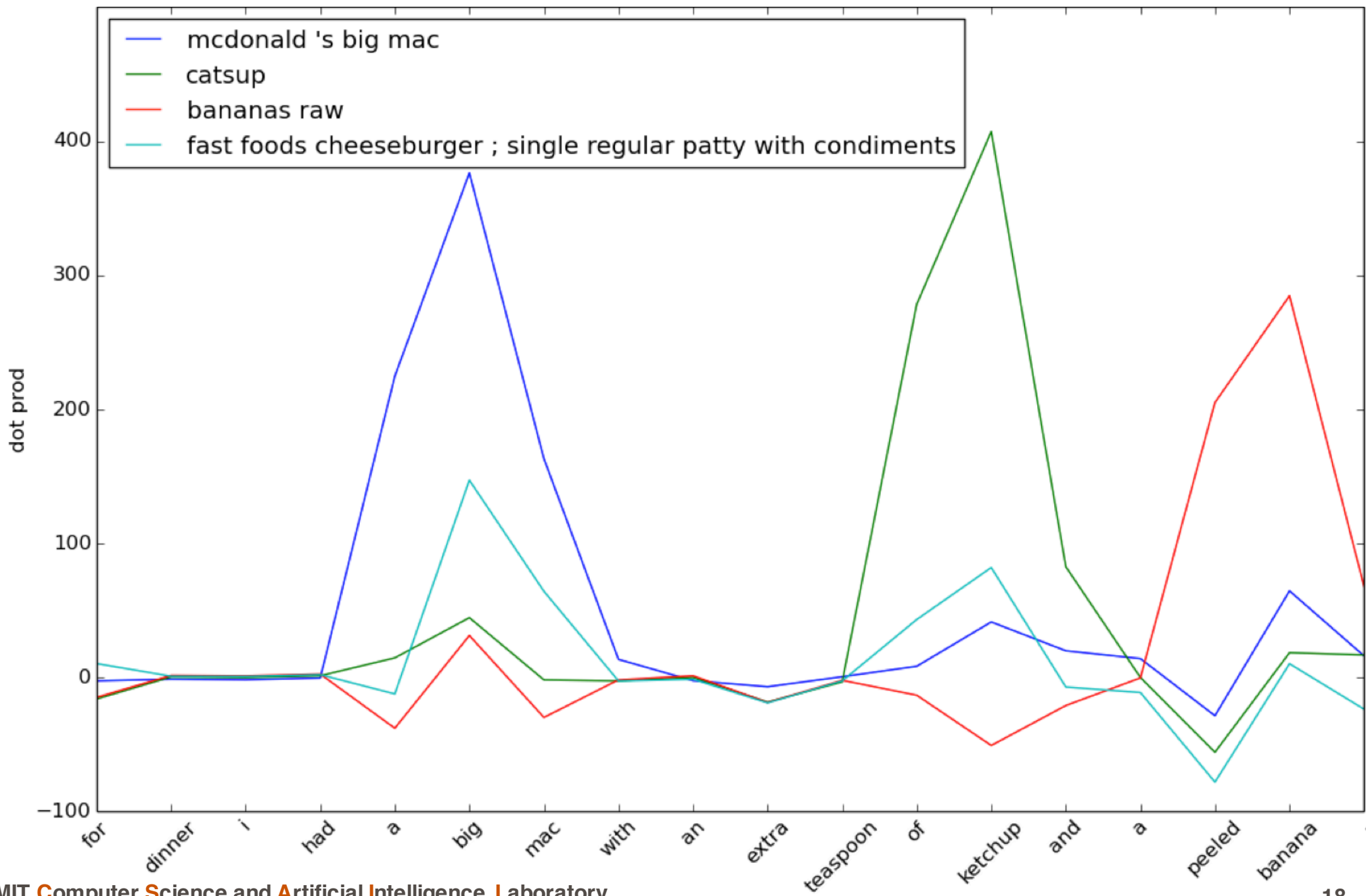
USDA Food

chili

Aligned Tokens

New Model Performs Better (101 Foods)

- **Recall: % of correctly predicted USDA foods**

Model	Recall
Old: CRF tagger + USDA Lookup	78.9%
New: CNN + FST Top-1	89.2%
New: CNN + FST Top-5	**90.6%**

Analysis: Spike Profile

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**