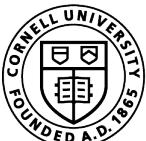




PlateClick

Bootstrapping Food Preferences
Through an Adaptive Visual Interface

Longqi Yang, Yin Cui, Fan Zhang, JP Pollak, Serge Belongie, Deborah Estrin



**CORNELL
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Cornell University
Department of Computer Science



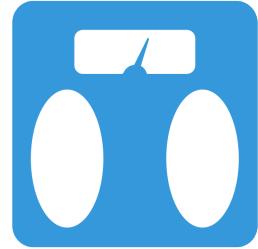
the small data lab



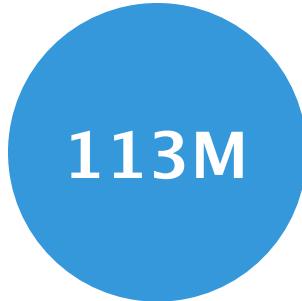
MOTIVATION

Food preferences learning is important!

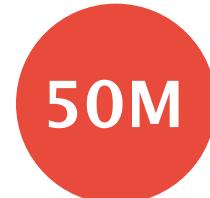
Health and Life



Obesity



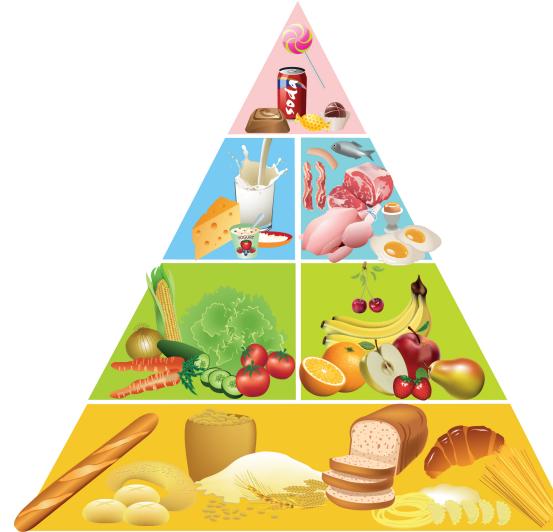
HBP



Diabetes



*Number of Americans Living with Diet-and Inactivity-Related Diseases



Unflavored Healthy diet
recommendations are of NO
Benefit!

Social Media and Commerce



A screenshot of the Yelp mobile application. At the top, there's a search bar with the placeholder "Restaurants". Below it, a list of eight restaurants is displayed with their names, ratings, reviews, distances, and price ranges. The restaurants listed are:

- 4. Babo Teahouse (300 ft)
- 5. Confucius Asian Bistro (.2 mi)
- 6. Bertucci's (.2 mi)
- 7. Raaz (.2 mi)
- 8. Fire & Oak (.3 mi)

At the bottom of the screen are three buttons: "Order Pickup or Delivery", "Make a Reservation", and a magnifying glass icon.



The Yummly website homepage. The top features the Yummly logo and a navigation bar with links for "Browse", "Create an account", and "Sign in". A large, vibrant image of various vegetables and dips serves as the background. Overlaid on this image is the text "Discover the world's recipes". Below the image is a search bar with the placeholder "Search recipes...". Further down, there are several categories and featured recipes: "Seasonal", "Popular Now", "Quick and Easy", "Weeknight Dinners", and "Yummly Dish". Below these categories are four smaller images of different dishes: "Parmesan Chicken", "Pasta Primavera", "Asparagus", and "Lipton Onion Dip".



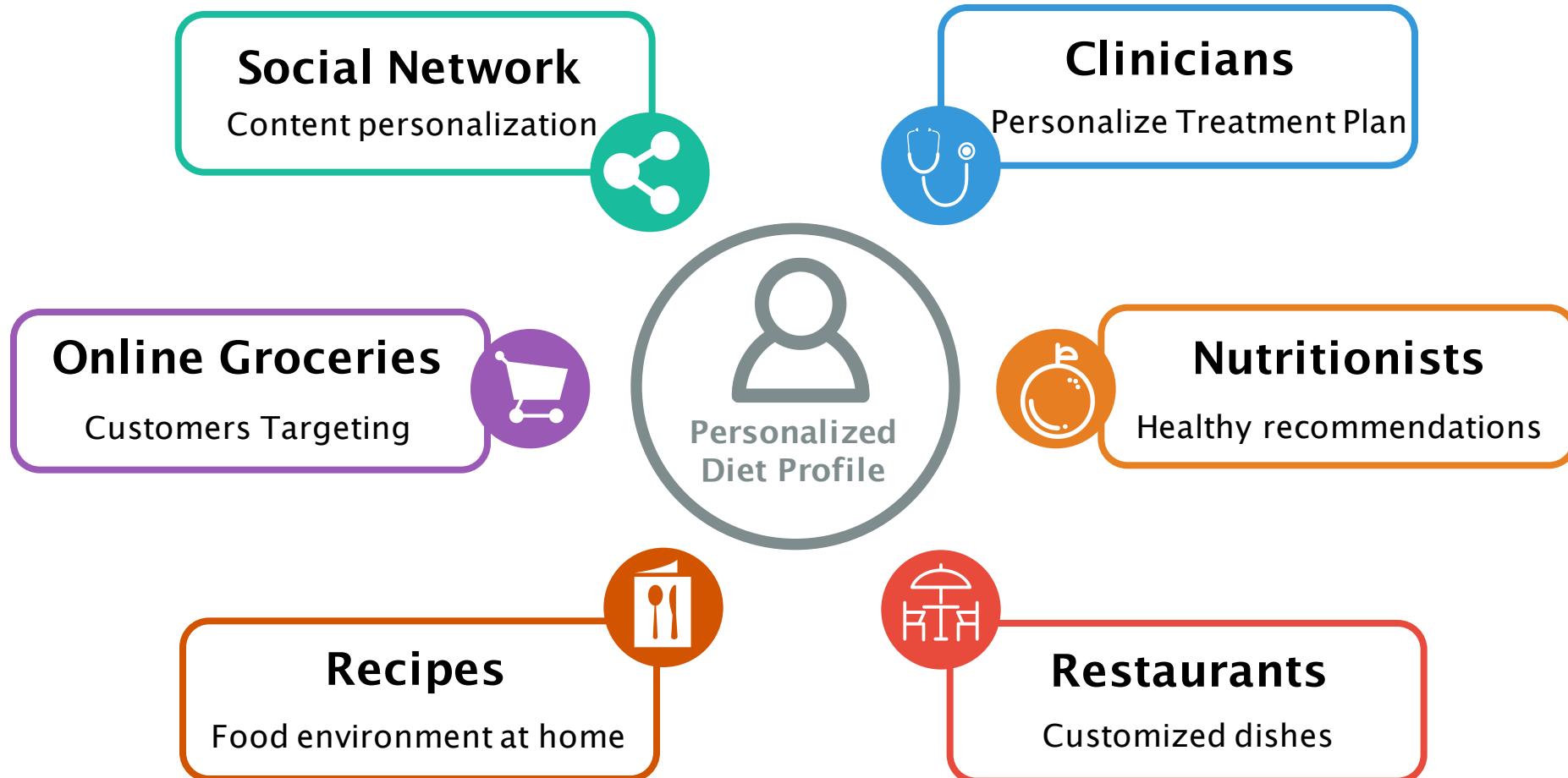
The Foursquare website search results for "Food near Kearny". The search bar at the top shows "I'm looking for..." and "Kearny". Below the search bar, a list of nearby food establishments is shown:

- Hamburgão** (8.4) 282 Kearny Ave, Burgers - \$ \$ \$
Rikki R. - February 20, 2013
Excellent food! Excellent and fast service(s)! You can absolutely come here anytime of the day. Prepare to get messy though.
- El Cubanito's Cafe** (8.0) 866 Kearny Ave, Cuban - \$ \$ \$
Vany G. - March 15, 2012
Super friendly and food is authentic, delicious and wallet-friendly! Try any of the daily specials. Finish with some espresso!
- The Bagel House** (7.8) 360 Belleville Tpke (Elm Street), Bagels - \$ \$
* Best bagels and sandwiches ever.* (4 tips)
* Best breakfast sandwiches around* (3 tips)

Each listing includes a small thumbnail image of the establishment and a "Save" button.

Personalized diet profile is the Key to user experience!

Our Vision



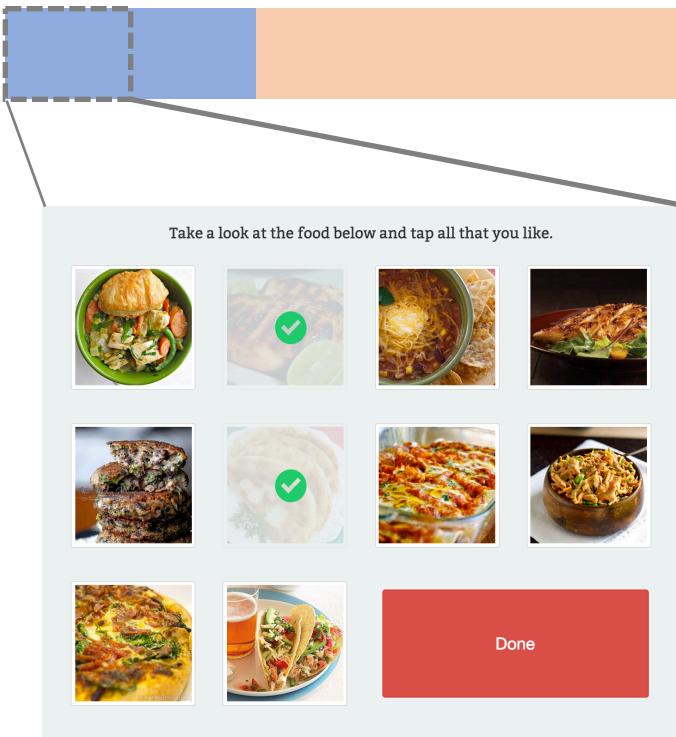
OUR SOLUTION

An adaptive visual interface



Exploration, 2 iters

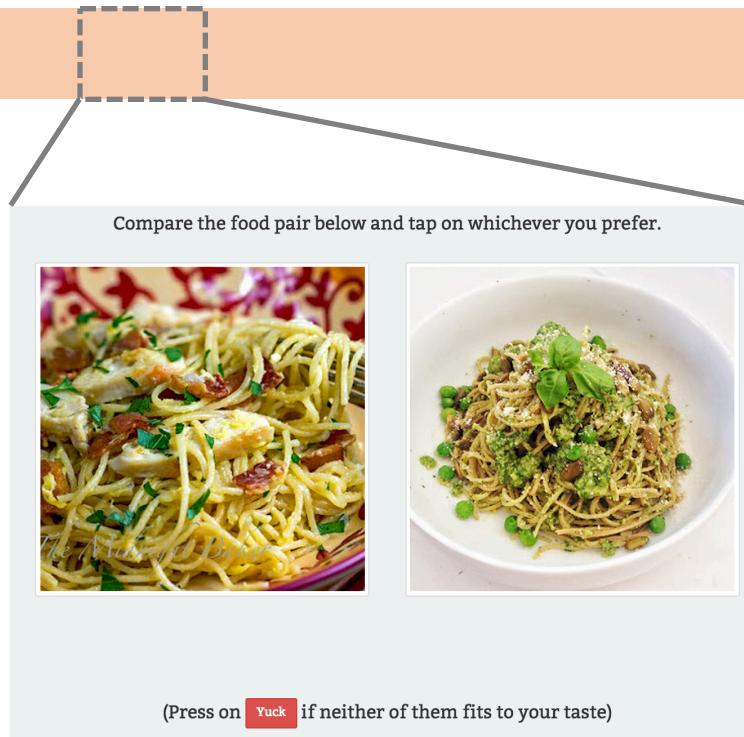
Start



10 food items

Exploration-exploitation: <15 iters

Diet Profile



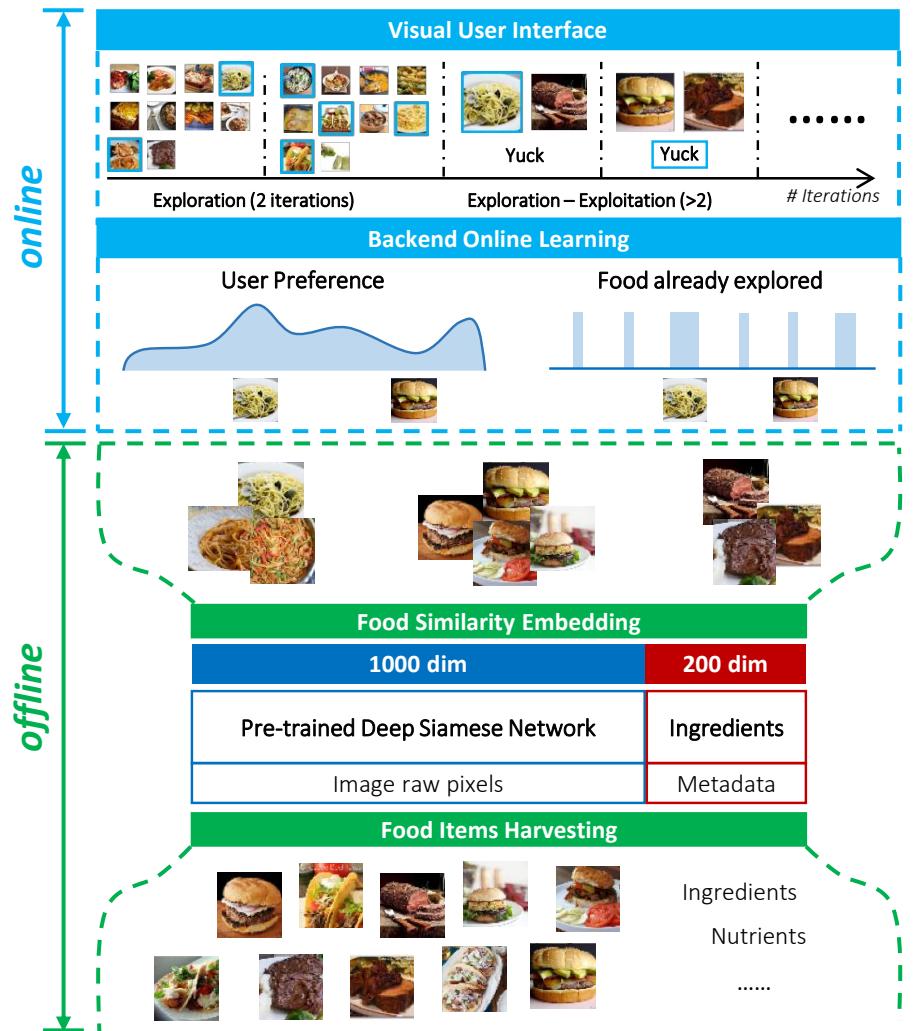
(Press on **Yuck** if neither of them fits to your taste)

Pairwise Comparison



- ✓ **Efficient:** *completed within a minute.*
- ✓ **Visual interface:** *low cognitive load, personalized and legible.*
- ✓ **Preference Elicitation:** *NO history required, NO ratings.*
- ✓ **Deep understanding of food images.**
- ✓ **Novel Online Learning Framework.**

System Design



Online Learning

Online Learning framework (LE + EE)

- What images to present to the user?
- How to update users' preferences?

Food Similarity Embedding

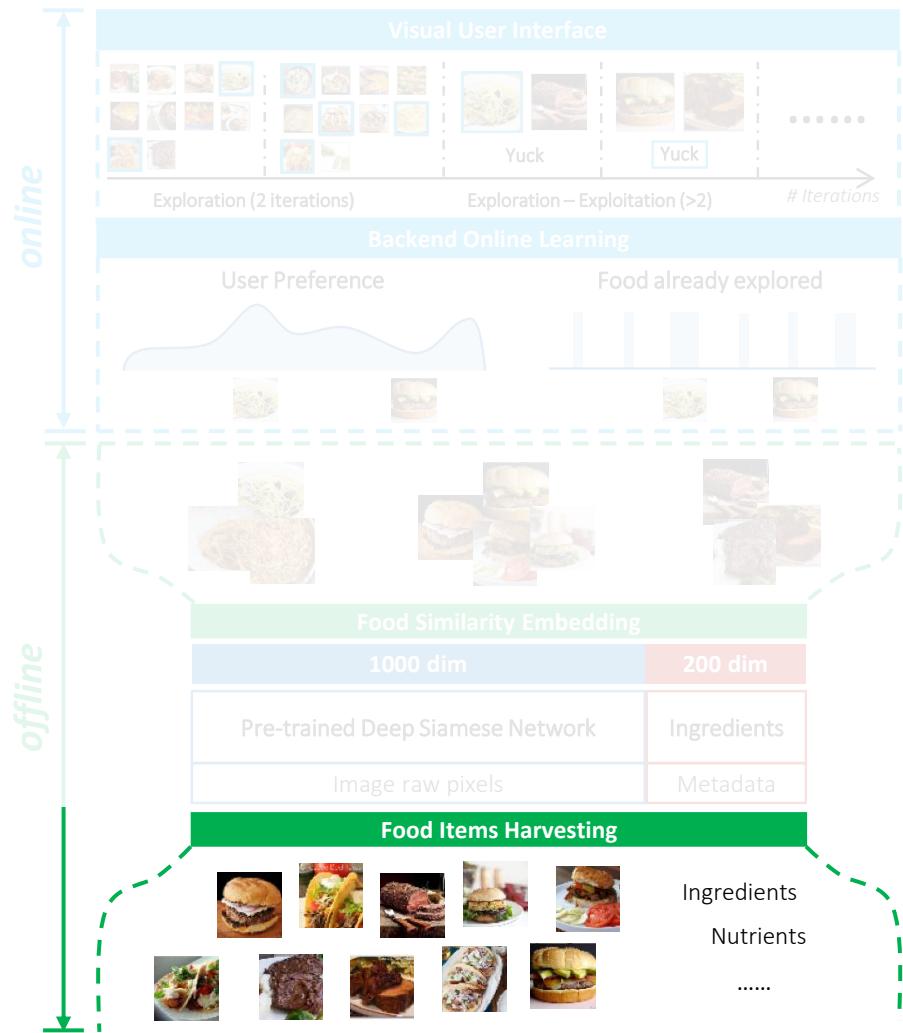
Users have **close** preferences for **similar** items

- Feature representation that can reflect similarities

Food Items Harvesting

- Food images and metadata.

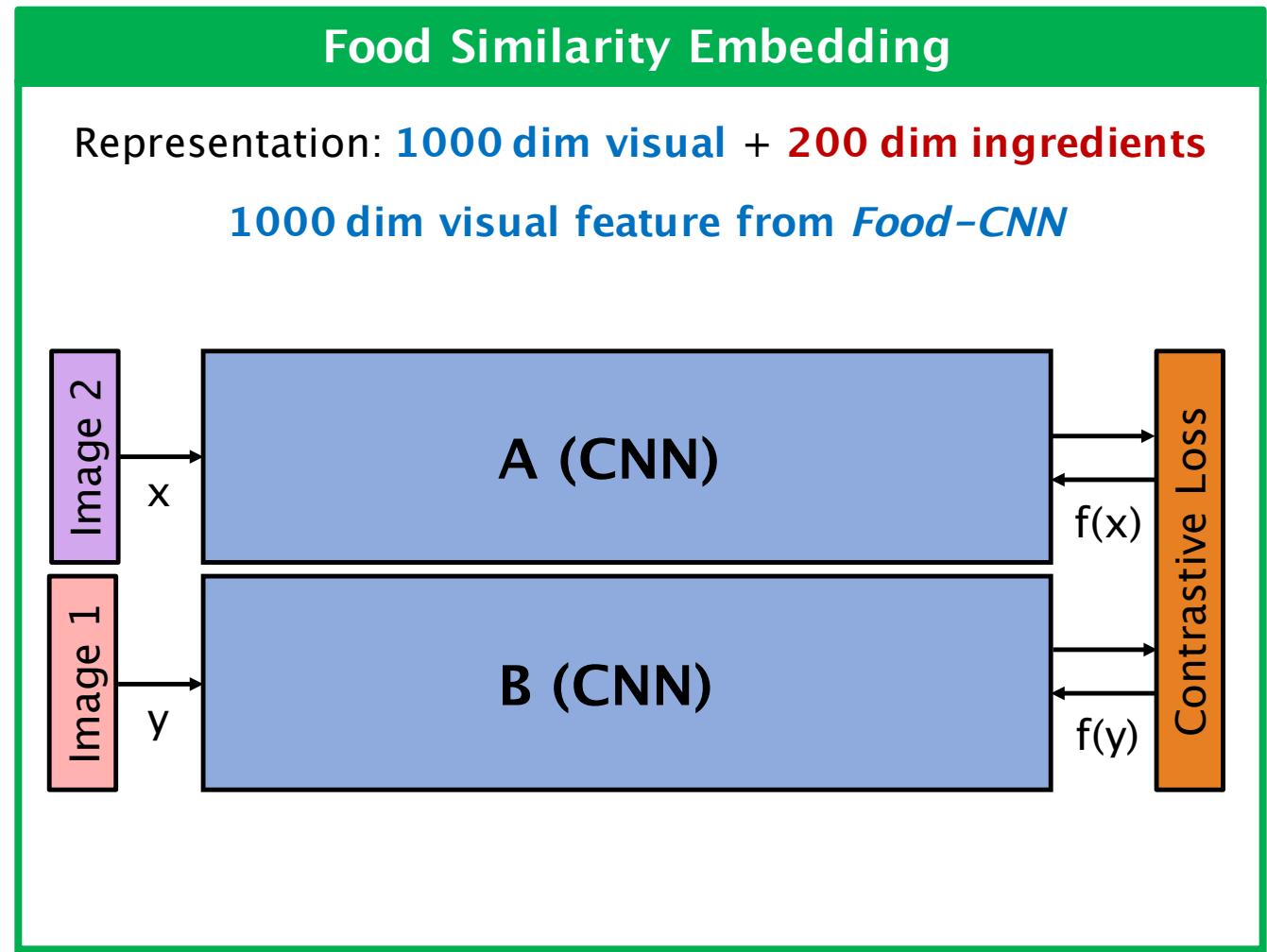
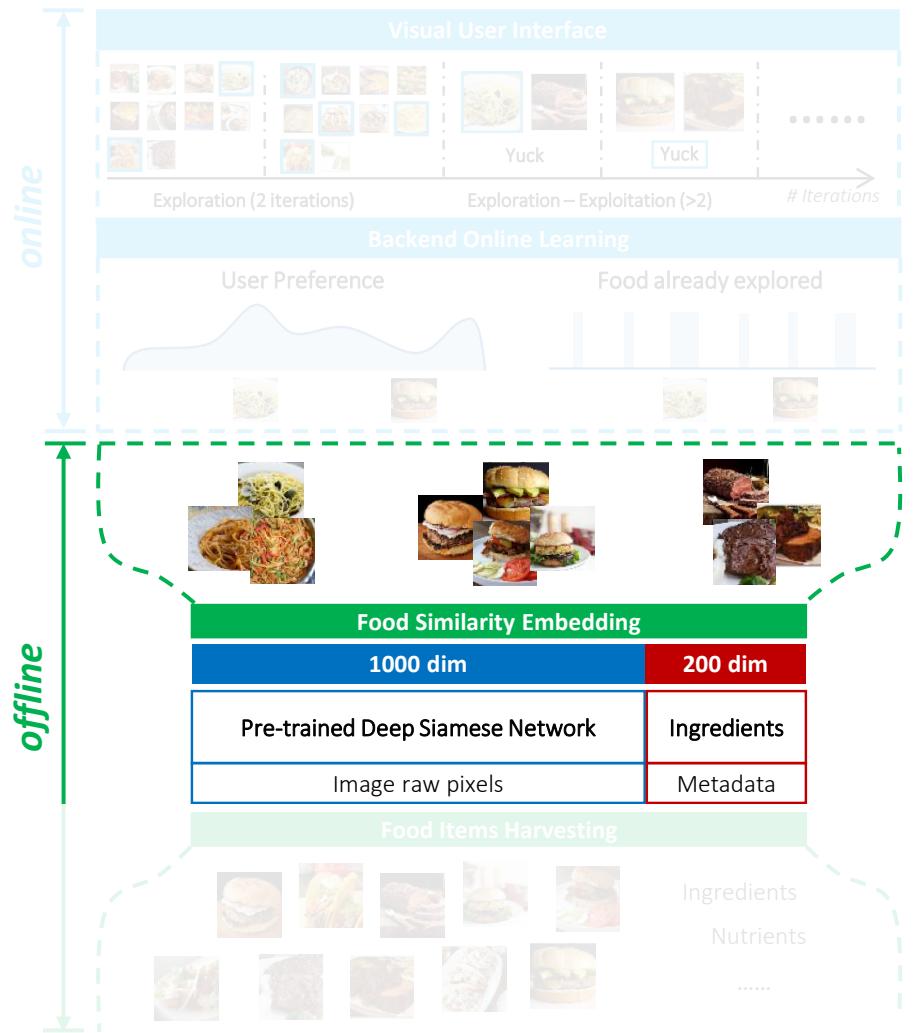
System Design: *offline*



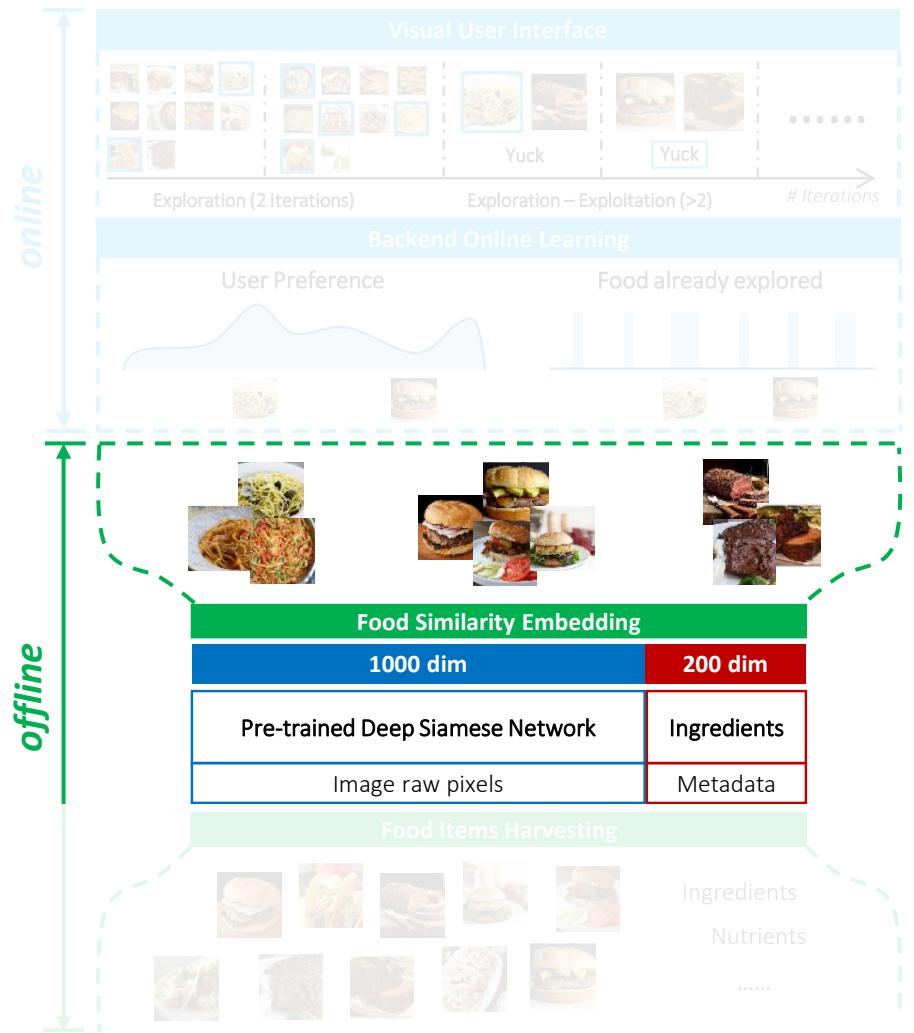
Food Items Harvesting

- 12,000 food items from Yummly API.
- Images + Metadata (ingredients, nutrients etc.)
- Outliers filtering, 10,028 items were used.

System Design: *offline*



System Design: *offline*



Food Similarity Embedding

Representation: **1000 dim visual + 200 dim ingredients**

1000 dim visual feature from Food-CNN

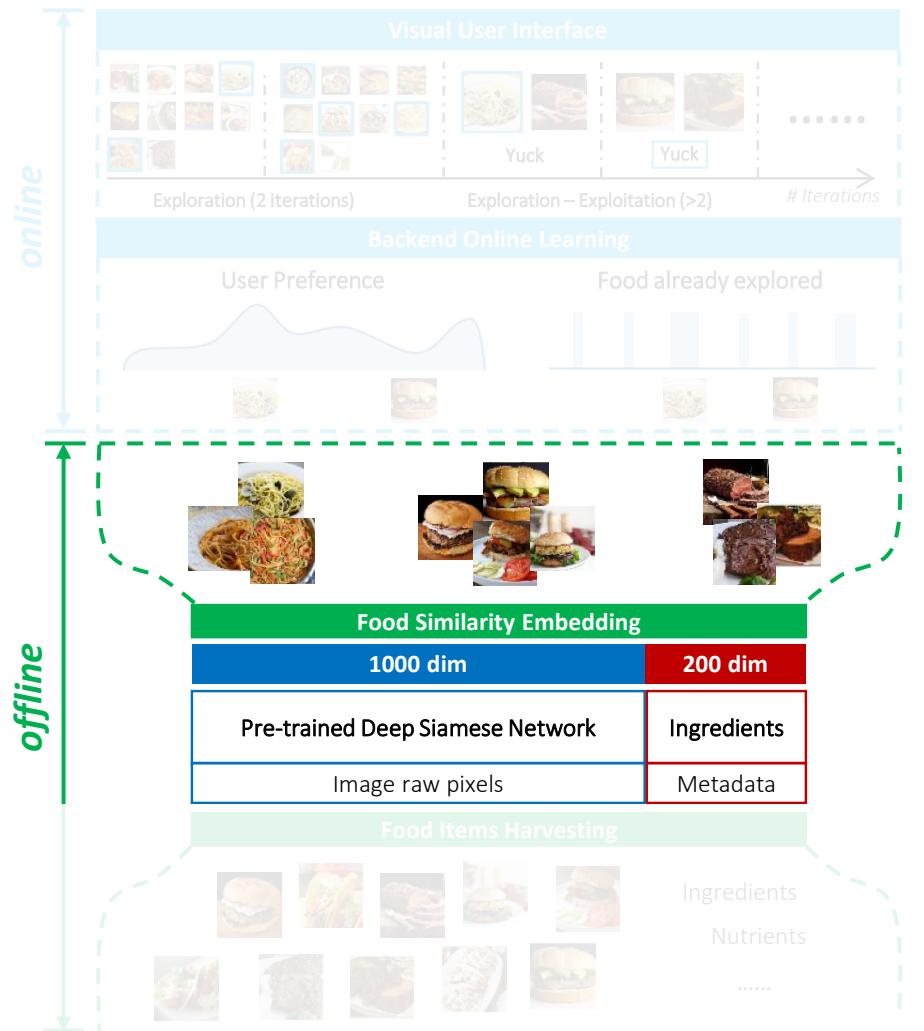
$$\{ \begin{matrix} \text{Hamburger} \\ \text{Burger} \end{matrix} \} \xrightarrow{l=1} \| \text{Hamburger} - \text{Burger} \| \approx 0$$

$$\mathcal{L} = \frac{1}{2} l D^2 + \frac{1}{2} (1 - l) \max(0, m - D)^2$$

$$\{ \begin{matrix} \text{Noodles} \\ \text{Burger} \end{matrix} \} \xrightarrow{l=0} \| \text{Noodles} - \text{Burger} \| > m$$

Pairs/Labels were sampled from Food-101 dataset

System Design: *offline*



Food Similarity Embedding

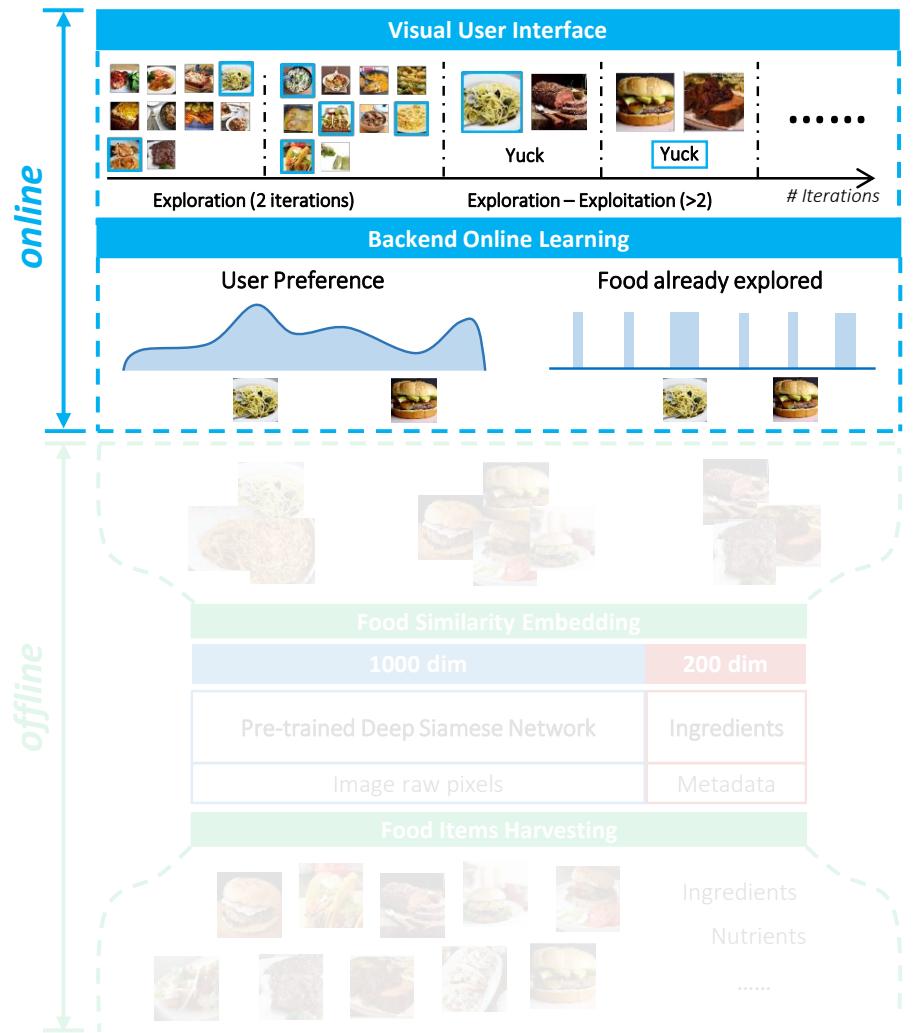
Representation: **1000 dim visual + 200 dim ingredients**

200 dim ingredients feature

- **Lemmatization and preprocessing.**
- **Filtering:** Top 200 ingredients.
- **Feature vector:** 0–1 vector denotes the existence of the ingredient.

Visual and **ingredients** feature vectors are normalized separately with l_1 norm

System Design: *online*



Online Learning

Food preferences representation:

$$\mathbf{p}^t = [p_0^t, p_1^t, \dots, p_{|\mathcal{S}|}^t] \quad \sum_i p_i^t = 1$$

Distribution of preferences over all food items in \mathcal{S}

\mathbf{p}^t : updated preference vector after **iteration t**

Two tasks at each iteration t :

- **User state update:** update \mathbf{p}^t based on the items presented and user's choices at **iteration $t-1$** .
- **Images selection:** Select a set of images to show at **iteration t** .

System Design: *online*

Online Learning

➤ User state update:

update p^t based on the items presented and user's choices at *iteration t-1*.

Users' selections → Image Labeling

Images selected → Label "+1"

Images not selected → Label "-1"

Images not presented → Label "0"

System Design: *online*

Online Learning

➤ User state update:

update p^t based on the items presented and user's choices at *iteration t-1*.

Label propagation with regularized optimization

$$\min_{\mathbf{u}} \sum_{j=1, j \neq i}^{|S|} \omega_{ij} (y_i - u_j)^2 + \sum_{j=1, j \neq i}^{|S|} (1 - \omega_{ij}) (u_j - y_j)^2$$

Smoothness

Fitting

Label Propagation and Exponentiated Gradient Algorithm (*LE*)

$$\omega_{ij} = e^{\frac{-1}{2\alpha^2} \|f^{s_i} - f^{s_j}\|} \quad u_j = \sum_{i=1}^{|S|} \omega_{ij} y_i \quad p_i^t \leftarrow p_i^{t-1} \times e^{\frac{\beta u_i^{t-1}}{p_i^{t-1}}}$$

System Design: *online*

Online Learning

- **Images selection:** Select a set of images to show at *iteration t*.

Exploration and Exploration-exploitation Algorithm (EE)

Exploration (Ten images): $t \leq 2$

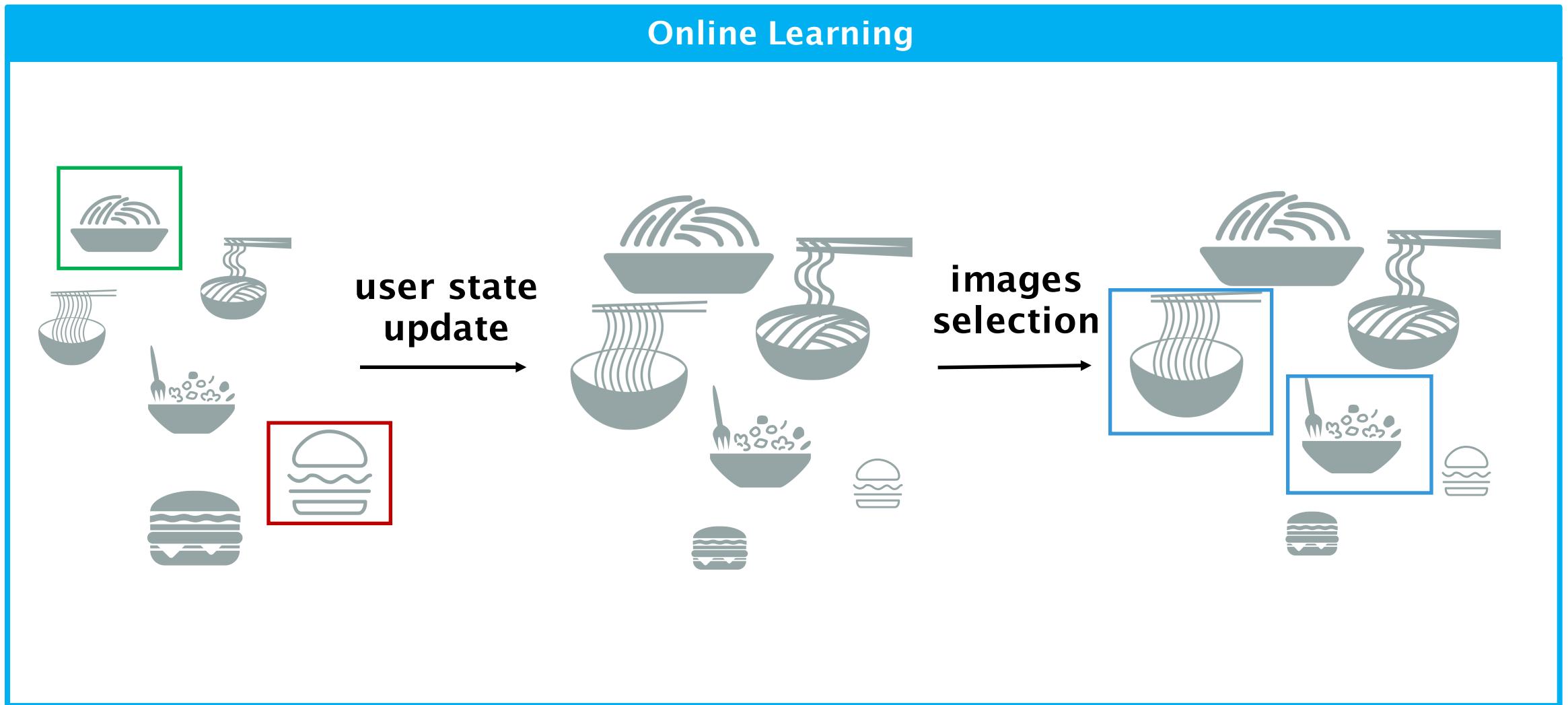
K-means++

Exploration-exploitation (Two images): $t > 2$

One Item that user “prefer” (with high value of p)

The other item that user hasn’t explored.

System Design: *online*



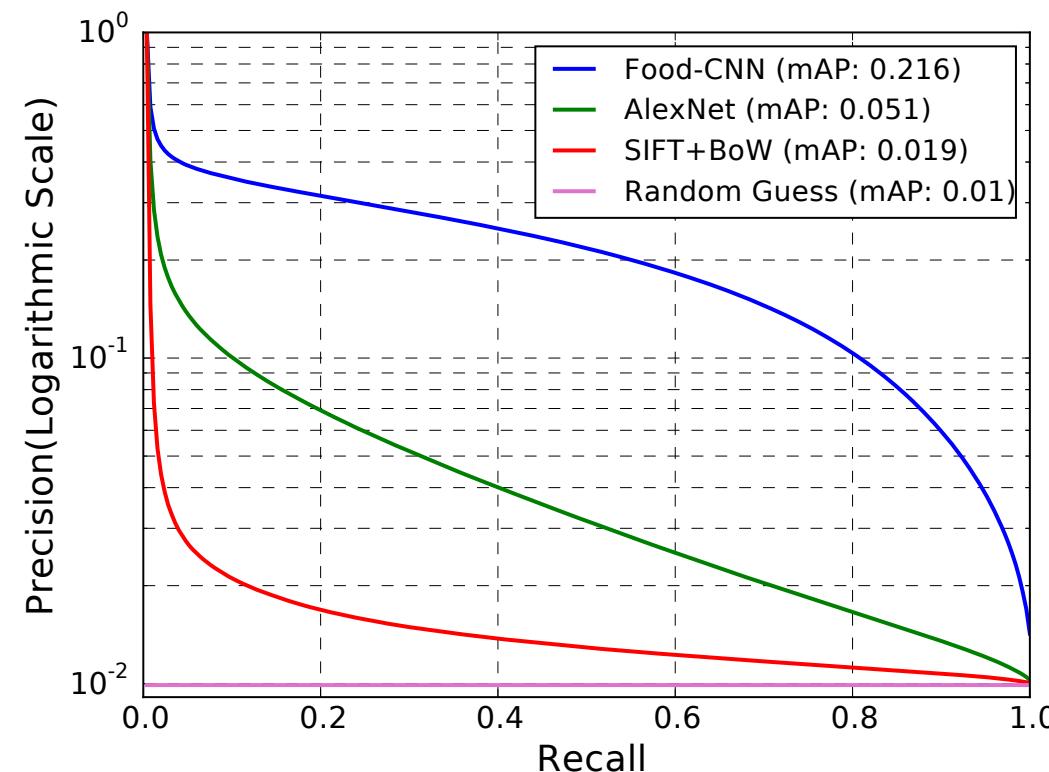
EXPERIMENTS AND USER STUDY

Evaluation, findings and evidence

Experiments: *embedding*

Clustering performance of *Food-CNN* (Tested on *Food-101 dataset*).

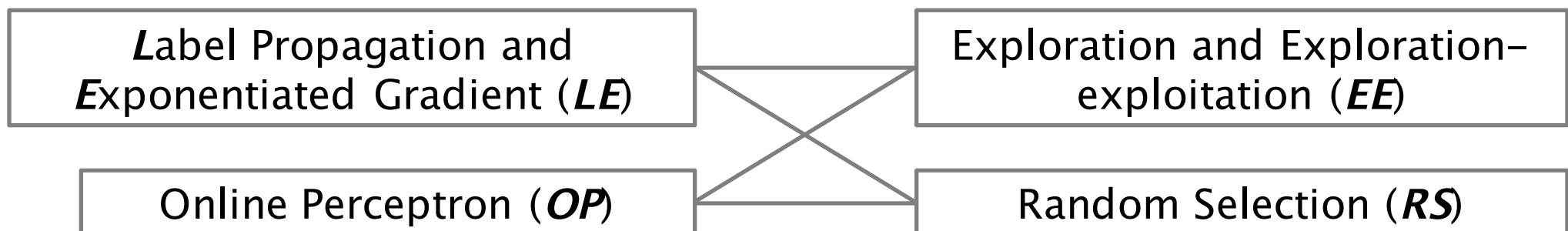
- K -neighbors of each test image, calculate the precision-recall for each K



Experiments: *user study*

- 227 anonymous users.
- Two factors were controlled in the study.

1st. Algorithm:



2nd. Number of iterations: 5/10/15

Experiments: *user study*

- Algorithm to test: *LE+EE*
- Trials: 1/3

Exploration Exploration-exploitation



One image from top 1% of preference value. (*unexplored*)

The other image from bottom 1% of preference value. (*unexplored*)

Experiments: *user study*

- Algorithm to test: *LE+EE*
- Trials: 2/3

Exploration Exploration-exploitation



PlateClick (5 iters) Testing (10 iters)

One image from top 1% of preference value. (*unexplored*)

The other image from bottom 1% of preference value. (*unexplored*)

Experiments: *user study*

- Algorithm to test: *LE+EE*
- Trials: 3/3

Exploration Exploration-exploitation

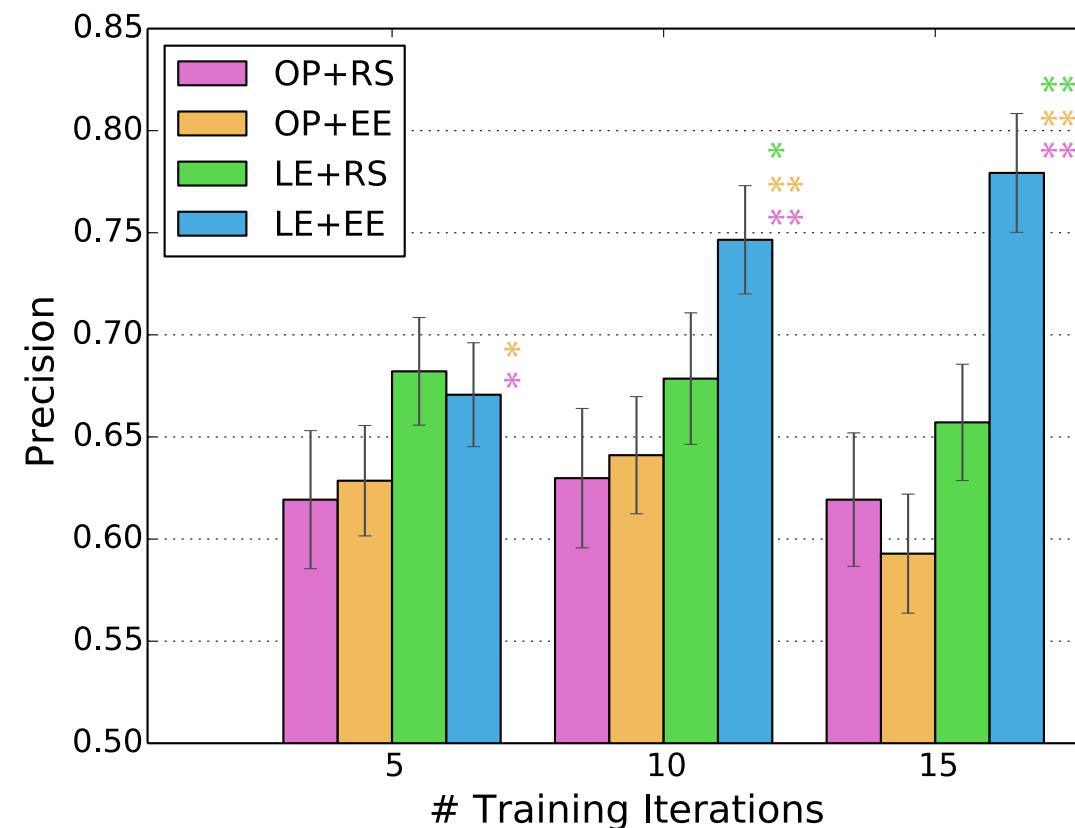


One image from top 1% of preference value. (*unexplored*)

The other image from bottom 1% of preference value. (*unexplored*)

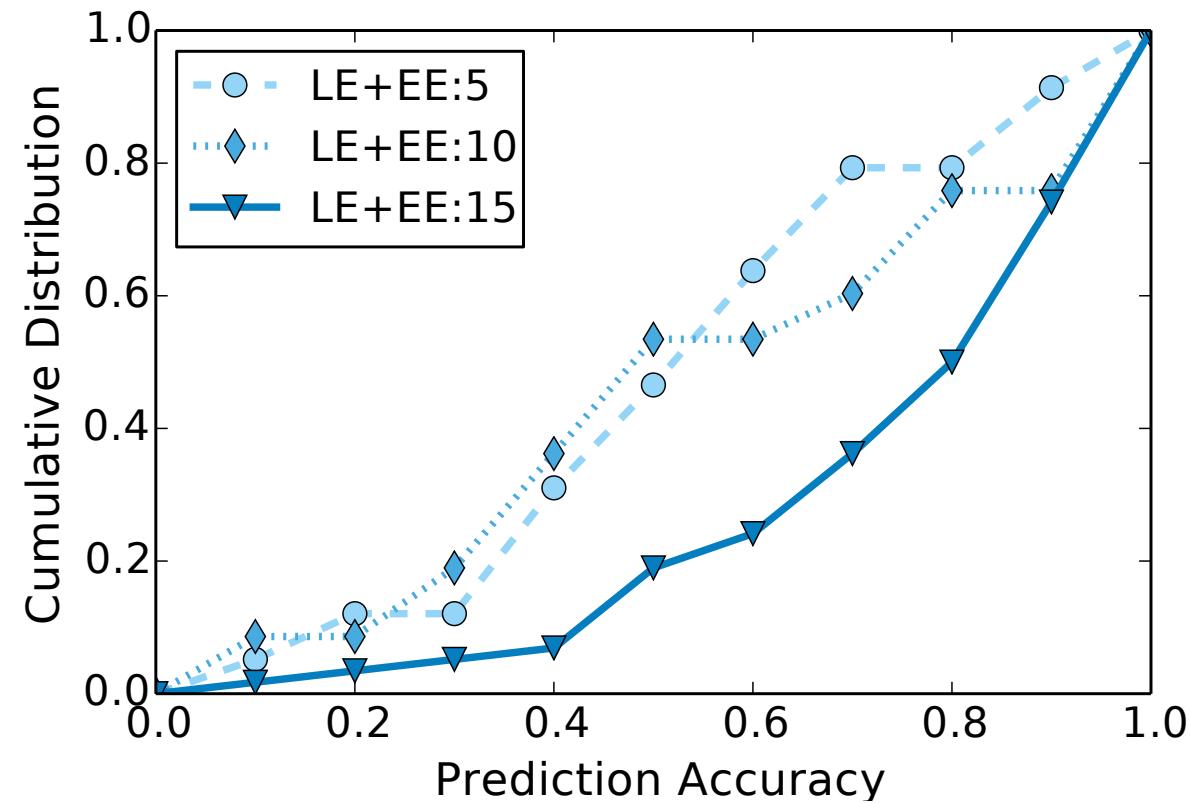
Experiments: *user study*

Prediction accuracy under different algorithms and number of iterations



Experiments: *user study*

Cumulative distribution of prediction accuracy for LE+EE algorithm



Conclusions and Future work



- Engine for food preferences learning.
- Applicable to general human-in-the-loop problems.

For more information:

<http://www.cs.cornell.edu/~ylongqi>

<http://smalldata.io/>



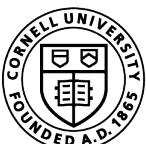
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the small data lab

