An Evaluation of Recommendation Algorithms for Online Recipe Portals

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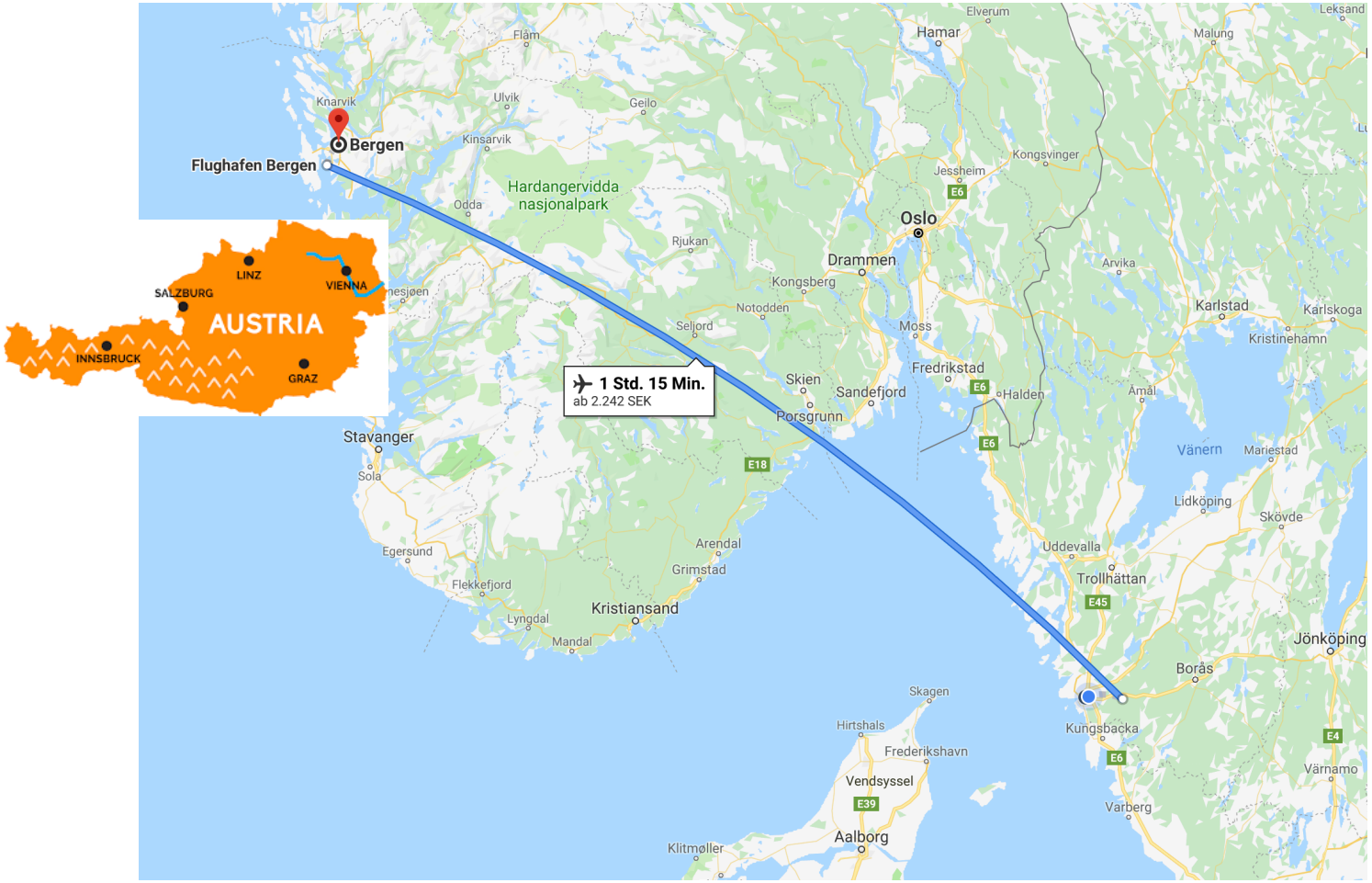
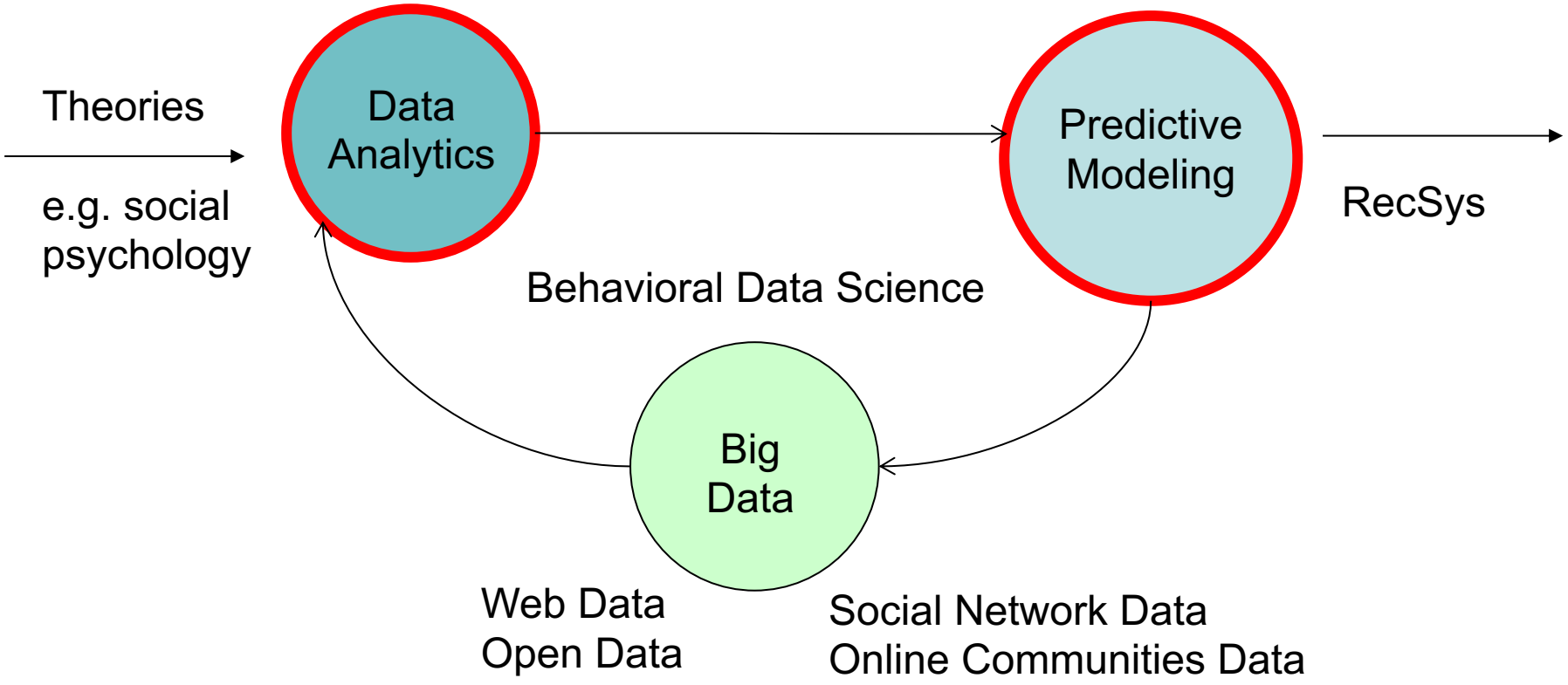
Where do I come from?



Research Focus

Understand how people behave



Agenda

- Motivation
- Current state-of-the-art in Food RecSys
- Content-based RecSys & Sim. Functions
- Protocol & Dataset
- Results
- Conclusions

Part 1:
Motivation

Why is research into Food Recsys Important?

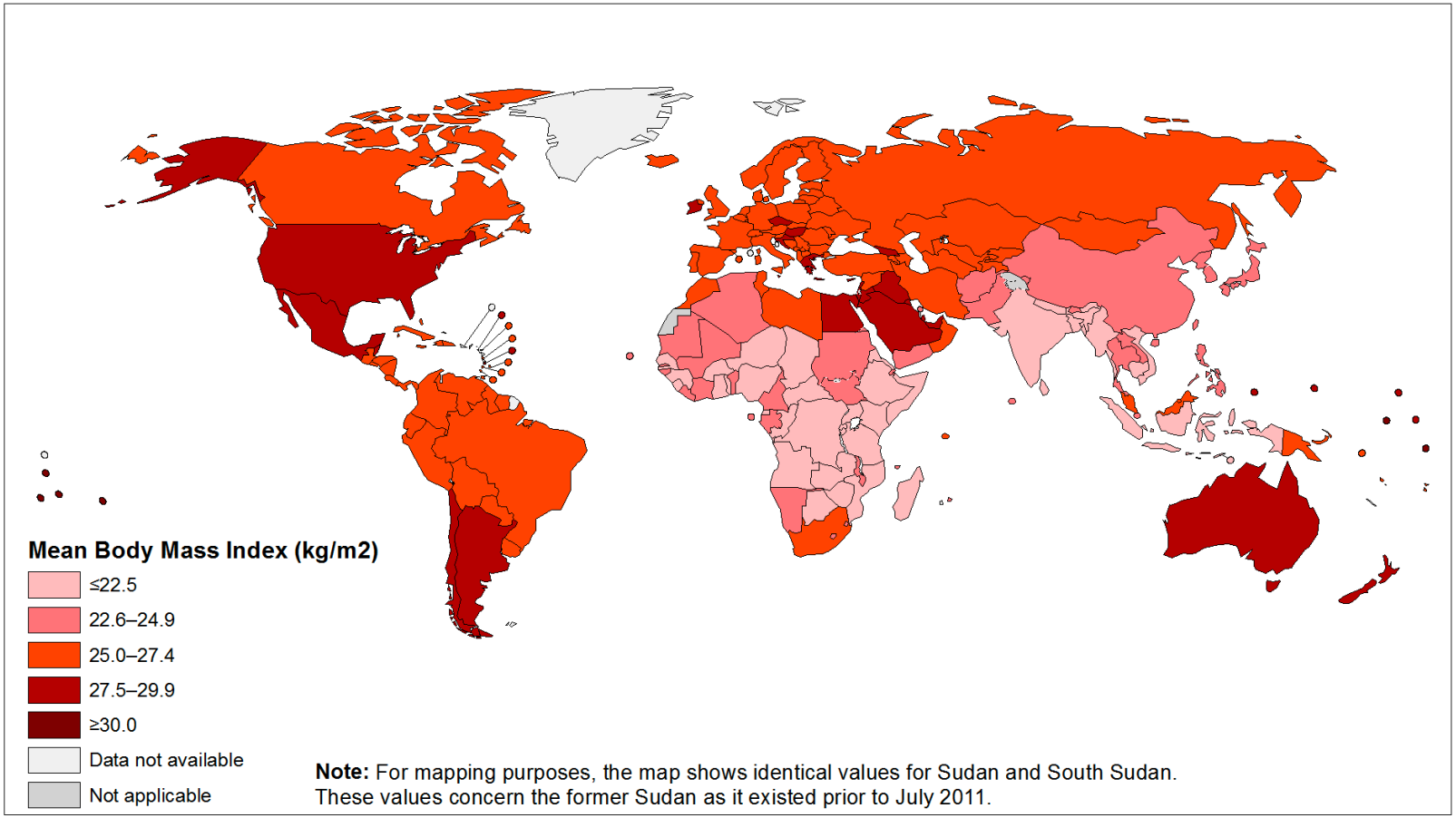
Why is that important?

- Food is one the main concepts that **shapes how good we feel** and **how healthy we are**

- According to the WHO, if common lifestyle risk factors, among others diet-related ones, were eliminated, **around 80% of cases of heart disease, strokes and type 2 diabetes, and 40% of cancers, could be avoided** (European Comission Recommendation C(2010) 2587 final, 2010).

BMI is increasing World Wide

Mean Body Mass Index (kg/m2), ages 18+, 2016 (age standardized estimate)
Male



Data Source: World Health Organization
Map Production: Information Evidence and Research (IER)
World Health Organization

World Health Organization

The approaches I am discussing today are all online food recommender approaches!

Why Online?

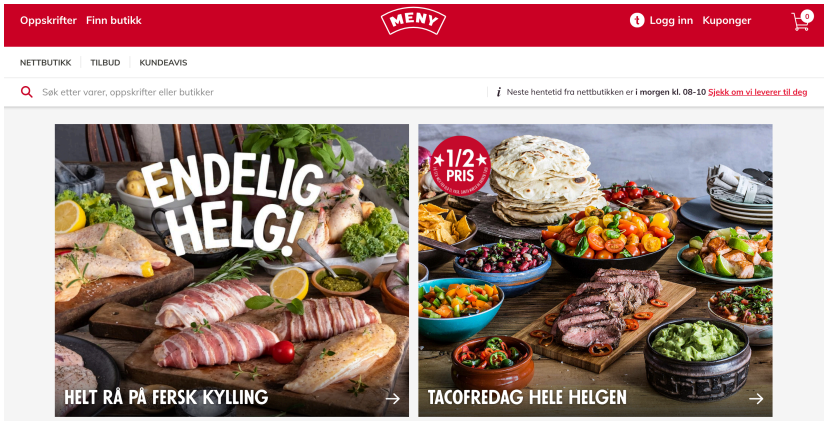
Most food interactions nowadays online

According to recent market research over 50%

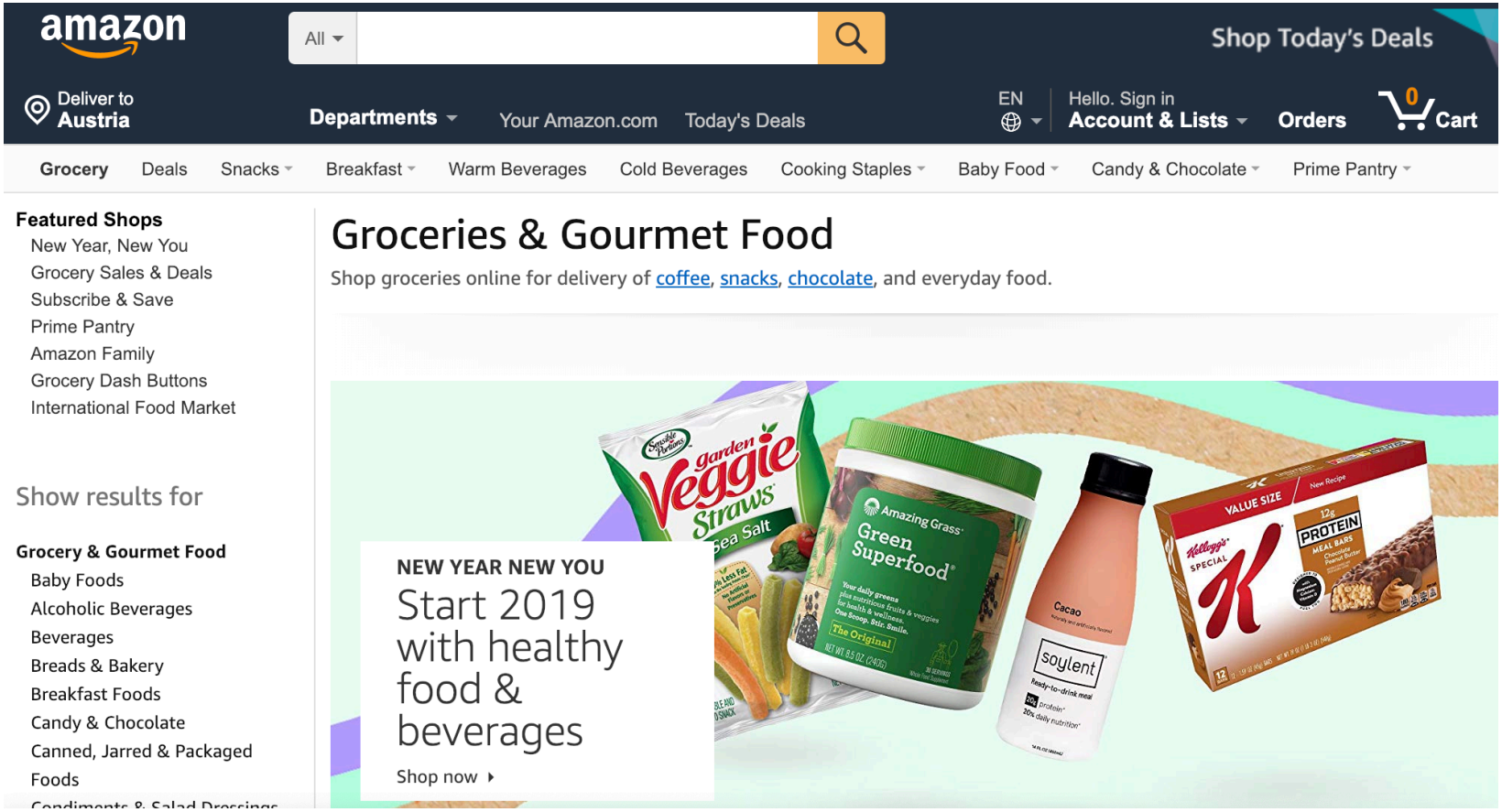
allrecipes

foodora

SPAR



Amazon


amazon
All
Shop Today's Deals
Deliver to Austria
Departments
Your Amazon.com
Today's Deals
EN
Hello. Sign in
Account & Lists
Orders
0
Cart
Grocery
Deals
Snacks
Breakfast
Warm Beverages
Cold Beverages
Cooking Staples
Baby Food
Candy & Chocolate
Prime Pantry
Featured Shops
New Year, New You
Grocery Sales & Deals
Subscribe & Save
Prime Pantry
Amazon Family
Grocery Dash Buttons
International Food Market
Show results for
Grocery & Gourmet Food
Baby Foods
Alcoholic Beverages
Beverages
Breads & Bakery
Breakfast Foods
Candy & Chocolate
Canned, Jarred & Packaged Foods
Groceries & Gourmet Food
Shop groceries online for delivery of coffee, snacks, chocolate, and everyday food.
NEW YEAR NEW YOU
Start 2019 with healthy food & beverages
Shop now
Garden Veggie Straws
Sea Salt
Amazing Grass
Green Superfood
The Original
Cacao
soylent
VALUE SIZE
PROTEIN
MEAL BARS

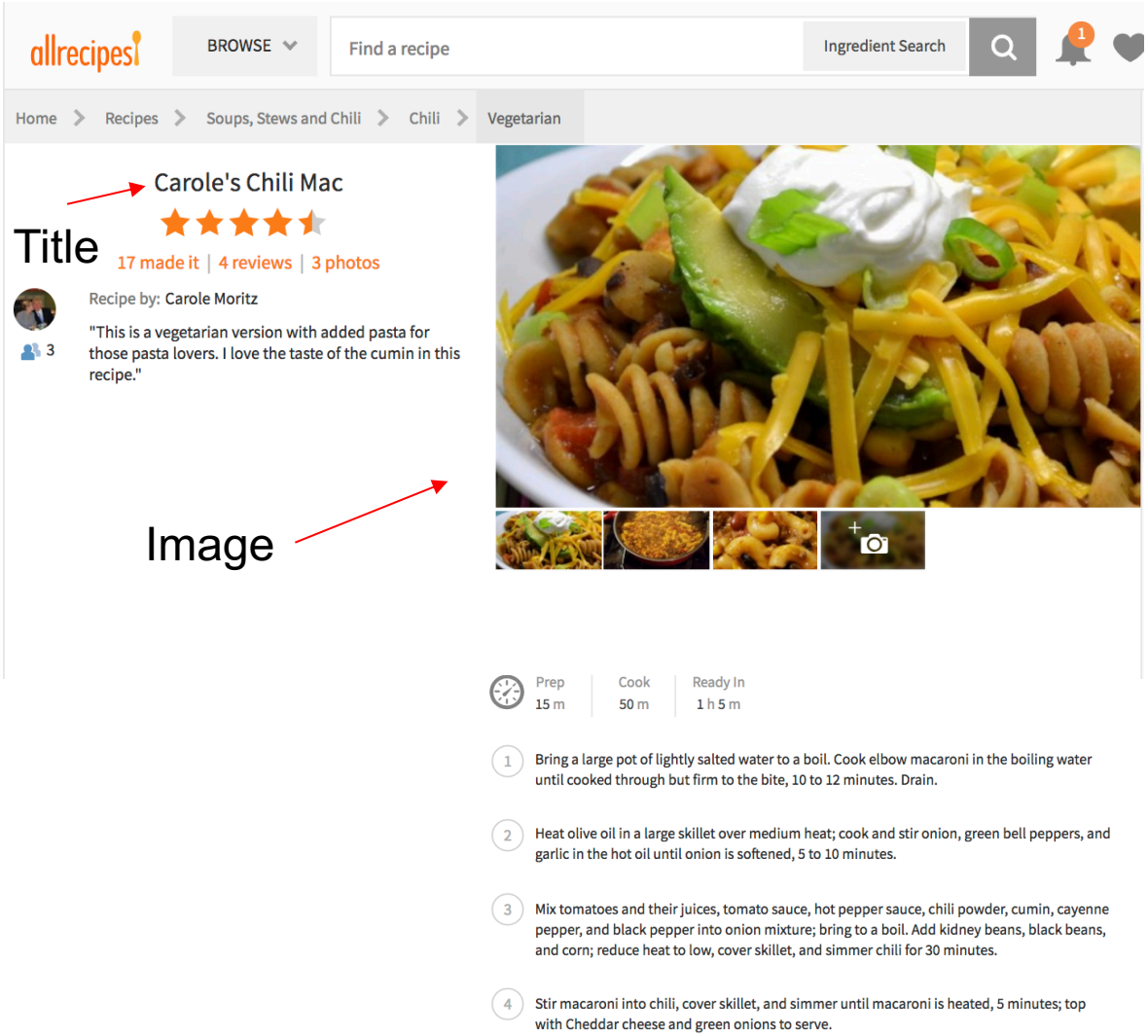
Part 2:
The Current State-of-the-art in Food RecSys

Food Recommender Systems: Important Contributions, Challenges and Future Research Directions. Trattner, C. and Elsweiler, D. Collaborative Recommendations: Algorithms, Practical Challenges and Applications, World Scientific Publishing Co. Pte. Ltd., 2018

Author(s)	Algorithm(s)	Person-alized	RecSys Type(s)	Feedback	Context/ Content Feature(s)	Dietary Constrains	Target	Dataset
(Elsweiler, Trattner & Harvey, 2017)	Logistic Random Forrest Naive Bayes	no	Recipes	Ratings Binary	Title Image Ingredients Nutrition Pop. & Appr	no	Single User	Allrecipes
(Trattner & Elsweiler, 2017)	LDA WRMF AR SLIM BPR MostPop User- ItemKNN	yes/no	Recipes Meal Plans	Bookmarks Ratings Comments	WHO-FSA health score	no	Single User	Allrecipes
(Cheng, Rokicki & Herder, 2017)	BPR MostPop	yes/no	Recipes	Ratings	City Size	no	Single User	Kochbar
(Yang et al., 2017)	Learning to Rank	yes	Recipes	Binary	Image Embeddings	yes	Single User	Yummly
(Rokicki, Herder, Kuśmierczyk & Trattner, 2016)	UserKNN MostPop	yes/no	Recipes	Ratings	Gender	no	Single User	Kochbar
(Ge, Elahi, Fernaández-Tobías, Ricci & Massimo, 2015)	MF CB	yes	Recipes	Ratings Tags	Tags	no	Single User	Wellbeing Diet Book
(Elsweiler & Harvey, 2015)	SVD-Hybrid	yes	Meal Plans (Set of recipes)	Ratings	Ingredients	yes	Single User	Quizine
(Sano, Machino, Yada & Suzuki, 2015)	UserKNN SVD Hybrid NL-PCA	yes	Groceries	Purchases	Food Categories	no	Single User	Grocery store data
(Trevisiol, Chiarandini & Baeza-Yates, 2014)	UserKNN CB	yes	Menus (Set of dishes)	Binary	Text Sentiment	no	Single User	Yelp
(Elahi, Ge, Ricci, Massimo & Berkovsky, 2014)	MF	yes	Recipes	Ratings Tags	tags	no	Group of Users	Wellbeing Diet Book
(Harvey et al., 2013)	CB, CF Logistic Reg. SVD-Hybrid	yes	Recipes	Ratings	Ingredients etc.	no	Single User	Quizine
(Teng, Lin & Adamic, 2012)	SVM	no	Recipes	Ratings	Ingredients Nutrition Cook effort Cook methods	no	Single User	Allrecipes
(Kuo, Li, Shan & Lee, 2012)	Graph-based CB	yes	Menus (Set of recipes)	Tags	Ingredients	no	Single User	Food
(El-Dosuky, Rashad, Hamza & El-Bassiouny, 2012)	CB KB	yes	Food items	Query	tags	no	Single User	USDA
(Freyne, Berkovsky, Baghaei, Kimani & Smith, 2011)	CF	yes	Meal plans (Set of recipes)	Ratings	-	no	Single User	Wellbeing Diet Book
(Ueta, Iwakami & Ito, 2011)	KB	yes	Recipes	Query	tags	no	Single User	Cookpad
(van Pinxteren, Geleijnse & Kamsteeg, 2011)	CB	yes	Recipes	Cooked recipes	Recipe content features	no	Single User	Smulweb
(Freyne & Berkovsky, 2010)	UserKNN CB Hybrid	yes	Recipes	Ratings	Ingredients	no	Single User	Wellbeing Diet Book
	UserKNN							

What types of features can we actually employ for CB in Food RecSys?

Problem



Ingredients

Ingredients

- 2 cups whole wheat elbow macaroni
- 2 teaspoons olive oil
- 1 small onion, chopped
- 2 green bell peppers, chopped
- 2 cloves garlic, minced
- 1 (14.5 ounce) can diced tomatoes, undrained
- 1 (8 ounce) can tomato sauce
- 1 tablespoon hot pepper sauce, or to taste
- 2 teaspoons chili powder, or more to taste
- 1 teaspoon ground cumin
- 1/4 teaspoon cayenne pepper
- 1/4 teaspoon ground black pepper
- 1 (15 ounce) can white kidney beans, drained and rinsed
- 1 (15 ounce) can black beans, drained and rinsed
- 1 (12 ounce) can whole kernel corn, drained
- 3/4 cup shredded reduced-fat Cheddar cheese
- 2 tablespoons chopped green onion, or to taste (optional)
- Add all ingredients to list

Directions

Part 3:
How do we calculate similarity between Recipes?

sim(a,b)

Linguine Pasta with Shrimp and Tomatoes

sim(a,b)

Ingredients

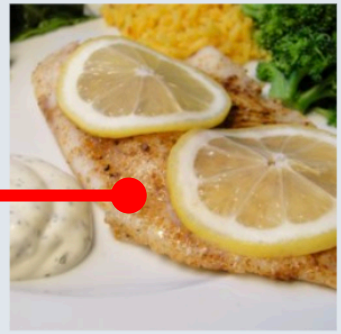
2 tablespoons olive oil
3 cloves garlic, minced
4 cups diced tomatoes
1 cup dry white wine
2 tablespoons butter
salt and black pepper to taste
1 (16 ounce) package linguine pasta
1 pound peeled and deveined medium shrimp
1 teaspoon Cajun seasoning
2 tablespoons olive oil

sim(a,b)

Directions

Heat 2 tablespoons of olive oil in a large saucepan over medium heat. Stir in the garlic, cook 2 minutes. Add the tomatoes, and wine. Bring to a simmer and cook 30 minutes, stirring frequently [illegible] simmered into a sauce, stir in the butter and season with salt and pepper. Fill a large pot with lightly-salted water, bring to a rolling boil, stir in the linguine and return to a boil. Cook the pasta uncovered, stirring occasionally, until the pasta has cooked through but is still firm to the bite,

Hudson's Baked Tilapia with Dill Sauce



Ingredients

4 (4 ounce) fillets tilapia
salt and pepper to taste
1 tablespoon Cajun seasoning, or to taste
1 lemon, thinly sliced
1/4 cup mayonnaise
1/2 cup sour cream
1/8 teaspoon garlic powder
1 teaspoon fresh lemon juice
2 tablespoons chopped fresh dill

Directions

Preheat the oven to 350 degrees F (175 degrees C). Lightly grease a 9x13 inch baking dish.
Season the tilapia fillets with salt, pepper and Cajun seasoning on both [illegible] seasoned fillets in a single layer in the baking dish. Place a layer of lemon slices over the fish fillets. I usually use about 2 slices on each piece so that it covers most of the surface of the fish. Bake uncovered for 15 to 20 minutes in the preheated oven, or until fish flakes easily with a fork.

sim(a,b)

Paper

Trattner, C. and Jannach, D. **Learning to Recommend Similar Items from Human Judgements**. User Modeling and User-Adapted Interaction Journal. 2019.

Features for Similar **Recipe** Recommendations

Table 1: Similarity metrics computed based on recipe titles, images, ingredients and cooking directions.

Name	Metric	Explanation
Title:LV	$sim(r_i, r_j) = 1 - \lvert dist_{LEV}(r_i, r_j)\rvert$	Title Levenshtein distance-based similarity
Title:JW	$sim(r_i, r_j) = 1 - \lvert dist_{JW}(r_i, r_j)\rvert$	Title Jaro-Winkler distance-based similarity
Title:LCS	$sim(r_i, r_j) = 1 - \lvert dist_{LCS}(r_i, r_j)\rvert$	Title Least Common Subsequence distance-based similarity
Title:BI	$sim(r_i, r_j) = 1 - \lvert dist_{BI}(r_i, r_j)\rvert$	Title Bi-gram distance-based similarity
Title:LDA	$sim(r_i, r_j) = \frac{LDA(Title(r_i)))\cdot LDA(Title(r_j))}{\lVert LDA(Title(r_i))\rVert \lVert LDA(Title(r_j))\rVert}$	Title LDA cosine-based similarity (LDA = LDA vector)
Image:BR	$sim(r_i, r_j) = 1 - \lvert BR(r_i) - BR(r_j)\rvert$	Image Brightness distance-based similarity
Image:SH	$sim(r_i, r_j) = 1 - \lvert SH(r_i) - SH(r_j)\rvert$	Image Sharpness distance-based similarity
Image:CO	$sim(r_i, r_j) = 1 - \lvert CO(r_i) - CO(r_j)\rvert$	Image Contrast distance-based similarity
Image:COL	$sim(r_i, r_j) = 1 - \lvert COL(r_i) - COL(r_j)\rvert$	Image Colorfulness distance-based similarity
Image:EN	$sim(r_i, r_j) = 1 - \lvert EN(r_i) - EN(r_j)\rvert$	Image Entropy distance-based similarity
Image:EMB	$sim(r_i, r_j) = \frac{EMB(r_i)\cdot EMB(r_j)}{\lVert EMB(r_i)\rVert \lVert EMB(r_j)\rVert}$	Image Embedding cosine-based similarity (EMB= image embedding vector)
Ing:COS	$sim(r_i, r_j) = \frac{amount(Ing(r_i))\cdot amount(Ing(r_j))}{\lVert amount(Ing(r_i))\rVert \lVert amount(Ing(r_j))\rVert}$	Ingredients Cosine similarity (amount-based weighting in grams per 100g of a meal)
Ing:JACC	$sim(r_i, r_j) = \frac{\{Ing(r_i)\}\cap\{Ing(r_j)\}}{\{Ing(r_i)\}\cup\{Ing(r_j)\}}$	Ingredients Jaccard similarity
Ing:TFIDF	$sim(r_i, r_j) = \frac{TFIDF(Ing(r_i))\cdot TFIDF(Ing(r_j))}{\lVert TFIDF(Ing(r_i))\rVert \lVert TFIDF(Ing(r_i))\rVert}$	Ingredients Text-based cosine similarity (TFIDF = TF-IDF weighted vector)
Ing:LDA	$sim(r_i, r_j) = \frac{LDA(Ing(r_i))\cdot LDA(Ing(r_j))}{\lVert LDA(Ing(r_i))\rVert \lVert LDA(Ing(r_j))\rVert}$	Ingredients LDA-based cosine similarity (LDA = LDA vector)
Dir:TFIDF	$sim(r_i, r_j) = \frac{TFIDF(Dir(r_i))\cdot TFIDF(Dir(r_j))}{\lVert TFIDF(Dir(r_i))\rVert \lVert TFIDF(Dir(r_j))\rVert}$	Cooking Directions Text-based cosine similarity (TFIDF = TF-IDF weighted vector)
Dir:LDA	$sim(r_i, r_j) = \frac{LDA(Dir(r_i))\cdot LDA(Dir(r_j))}{\lVert LDA(Dir(r_i))\rVert \lVert LDA(Dir(r_j))\rVert}$	Cooking Directions LDA cosine-based similarity (LDA = LDA vector)

Part 4:
Experiment & The Dataset

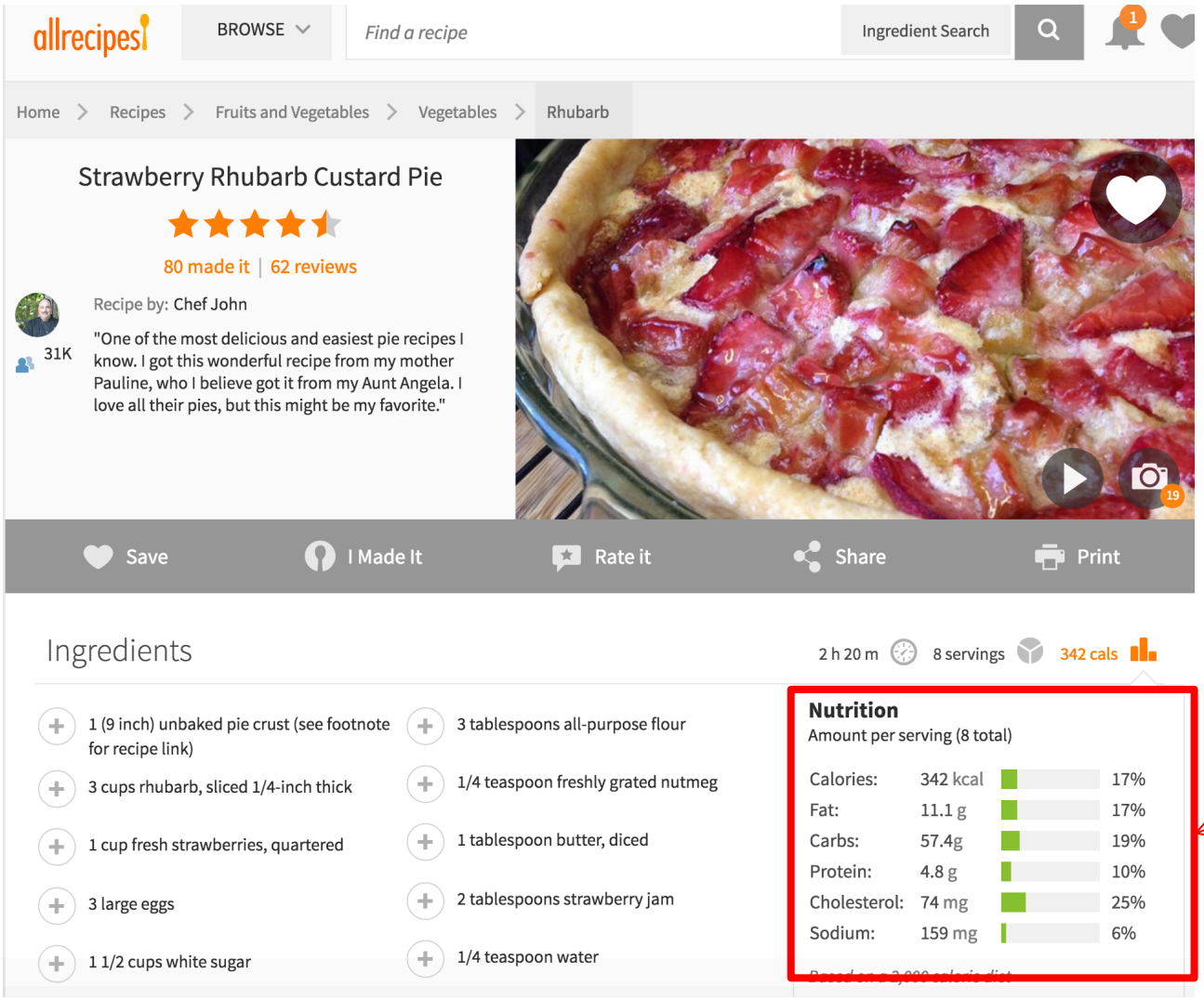
Offline Evaluation with 10-fold Cross-Validation

LibRec/AUC

http://allrecipes.com

Basic statistics:

- 60,983 recipes
- 1,032,226 ratings
- 17,190,534 bookmarks



Nutrition Facts to compute FSA

Determining the healthiness of recipes

What the colours mean:

RED means **HIGH**
*indicating that the food is **high** in fat, sugars or salt*

It's fine to eat this food occasionally or as a treat, but think about how often you choose it and how much of it you eat.

AMBER means **MEDIUM**
*making it an **OK** choice*

Although going for green is even better!

GREEN means it's **LOW**

Which makes it a healthier choice.

FSA food health criteria

Trattner, C. Elsweiler, D. and Simon, H. Estimating the Healthiness of Internet Recipes: A Cross-Sectional Study. Frontiers in Public Health, 2017.

Allrecipes.com popularity

How popular is allrecipes.com?

Alexa Traffic Ranks

How is this site ranked relative to other sites?

Global Rank

730 ▼ 2

Rank in United States

217

Country	Percent of Visitors	Rank in Country
United States	69.6%	217
Canada	8.0%	219
United Kingdom	2.5%	1,375
Germany	2.0%	2,017
India	1.3%	4,349

According to Alexa.com

Part 5:
Results

Table 2: Results of the recommender experiment – collaborative (CF) vs content-based (CB) – in the dense data sample with all users. Best features in each set (CF and CB) are bolded. Top-5 (↑) and Bottom-5 (↓) single content features are also marked.

Method	Algorithm	AUC
CF	BPR	**.7094**
	WRMF	.6881
	UserKNN	.6962
	ItemKNN	.6909
	MostPopular	.6864
	LDA	.6863
CB	Title:Levenstein-Distance	.5468 (↑)
	Title:Bigram-Distance	.5500 (↑)
	Title:LCS-Distance	.5424
	Title:LDA-Text-Cosine	.5353
	Title:Jaro-Winkler-Distance	.5324
	Title:All	.5523
	Image:Cosine-Embeddings	.5322
	Image:Colorfulness-Distance	.5072 (↓)
	Image:Contrast-Distance	.5175
	Image:Sharpness-Distance	.5109
	Image:Entropy-Distance	.5080 (↓)
	Image:Brightness-Distance	.4991 (↓)
	Image:All	.5425
	Ingredients:Cosine-Text	.5547
	Ingredients:Cosine-LDA-Text	.5653 (↑)
	Ingredients:Jaccard	.5502
	Ingredients:Cosine	.5575
	Ingredients:All	.5718
	Directions:Cosine-LDA-Text	.5606 (↑)
	Directions:Cosine-Text	.5210
	Directions:All	.5731
	Ratings:Number-Distance	.4789 (↓)
	Ratings:Average-Distance	.4832 (↓)
	Ratings:All	.5249
	Health:FSA	.5775 (↑)
	CB:All	**.5883**
	Random	.4989

CF vs CB in Recipe RecSys

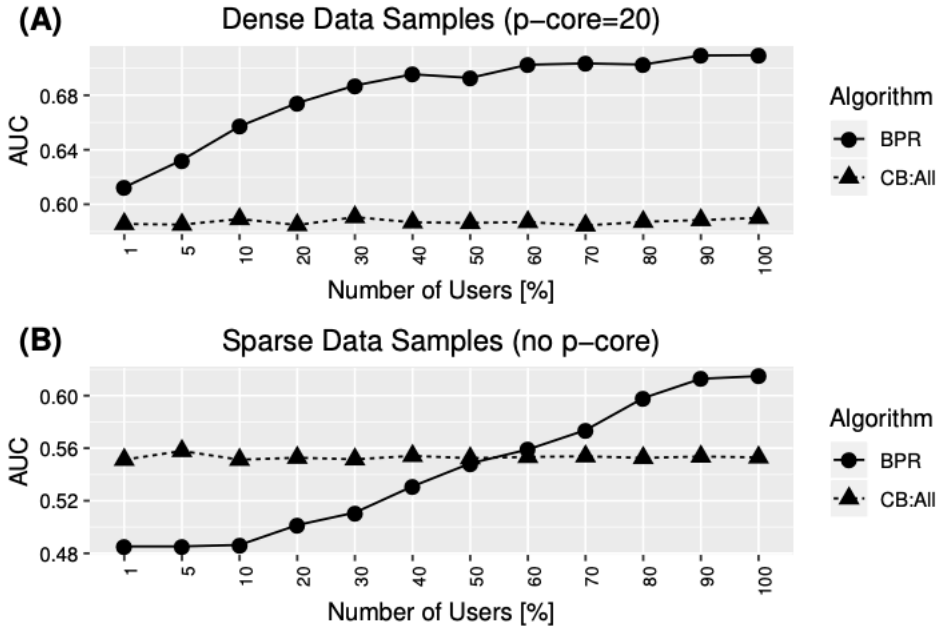


Figure 1: (A) shows the results in the dense data samples (= p-core filtered) where each user has at least 20 item interactions and each item is at least 20-times interacted with, (B) shows the results in the sparse data samples (=no p-core).

Summary

- **CF methods consistently outperform** CB methods over the full dataset.
- **CF requires** either a small number of **highly active users** or over six hundred users, selected randomly to achieve competitive performance.
- **There is a useful signal in the CB facets**, which would be useful in cold-start situations.
- **One of the most robust content features is the nutritional healthiness** of the recipe as deined by a measure derived from the United Kingdom Food Standards Agency (FSA).

What is the Future?

Sustainable Food Recommender Systems

What online data say about eating habits. Trattner, C. and Elsweiler, D. NATURE Sustainability, 2019

Thank you!

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Twitter: @ctrattner


THANK
YOU
GRACIAS
ARIGATO
SHUKURIA
DANKSCHEEN
BIYAN
SHUKRIA
TINGKI
YAQHANYELAY
TASHAKKUR ATU
SUKSAMA
EKHMET
MEHRBANI
GRAZIE
MAAKE
KOMAPSUMNIDA
JUSPAXAR
GOZAIMASHITA
EFCHARISTO
PALDIES
BOLZİN
MERCI
MINMONCHAR
SPASSIBO
SNACHALHUYA
NUHUN
CHALTU
WABEEJA
MAITEKA
YUSPAGARÀTAM
HUI
GUI
HÄTUR
SPASIBO
DENKAUJA
NENACHALHYA
UNALCHÉESH
EKOJU
SIKOMO
MAKÈTAI
DHANYABAAD
ANIHIA
ATTO
MERSI
SANCO
MERASTAWHY
GAEJTHO
LAH
TAVTAPUCH
MEDAWAGSE
AGUYJE
FAKAAUE
BAIKA