Centre for
Data Analytics

Insight

Recipe Recommendation Reasoning on Features: Ensemble Topic Modeling Based Approach

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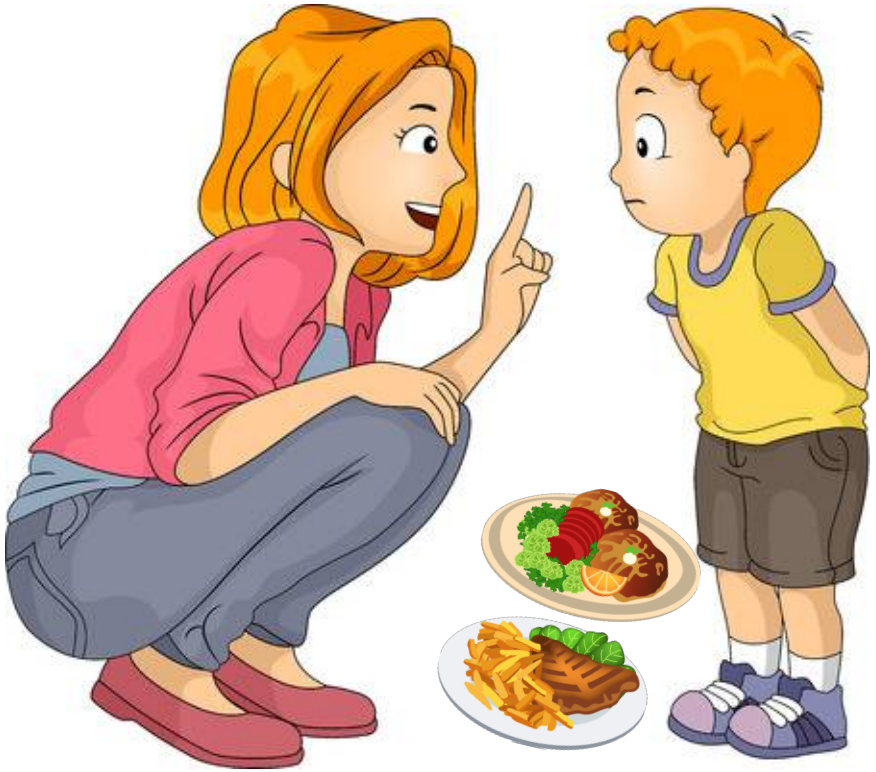
Why food recommendation is interesting ?

Food choice is multifaceted, multilevel, contextual, dynamic, integrated and diverse

-Jeffery Sobal

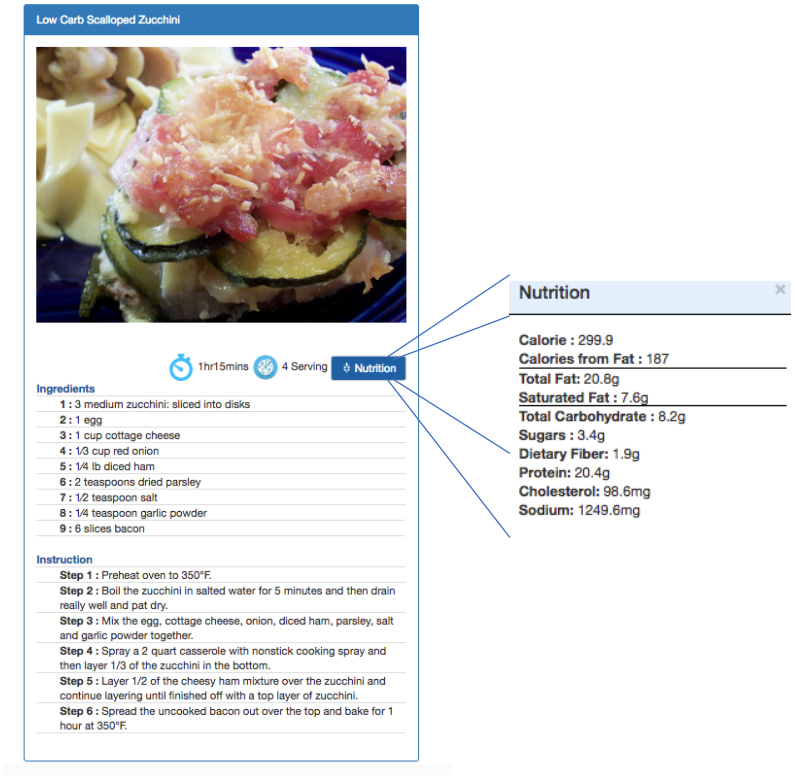


Core Challenges in Food/Recipe Recommendation Domain

- Capturing user's preference on food related aspects.
- Identifying coherent content and context information.
- Getting access to standardized food and nutrition data.
- Representation of Food Data
- Mapping health on recommendations.
  - Measuring healthiness of food item.
  - Measure user's nutrient requirement.
- Diversity
- Coverage

- Pursue user to choose healthier options.
- Achieve continuous and regular user engagement.

What is a recipe?



Recipe is a Story : Document

Title: Yummy mashed potatoes
Ingredients: butter, cream, potatoes, salt and pepper
Instruction : cook potatoes in bowling water until tender but still firm, In a small saucepan heat butter and cream at low heat. Using a potato masher slowly blend cream mixture into potatoes. Season with salt and pepper to taste.

How RS reads a recipe?

Frequency Count :

Occurrence of terms in each document

Terms	Frequency
Potatoes	4
saucepan	1
heat	2
title	1
…..	
in	2
salt	2
tender	1
a	2

Recipe 1

Title: Yummy mashed potatoes
Ingredients: potatoes, butter, cream, salt and pepper
Instruction : cook potatoes in bowling water until tender but still firm, In a small saucepan heat butter and cream at low heat. Using a potato masher slowly blend cream mixture into potatoes. Season with salt and pepper to taste.

Bag of word representation

a	in	potatoes	salt	low	Sauce pane	but					masher			blend
2	2	4	2	1	1	1					1			1

Hundreds of thousands of Documents : Recipe Corpus

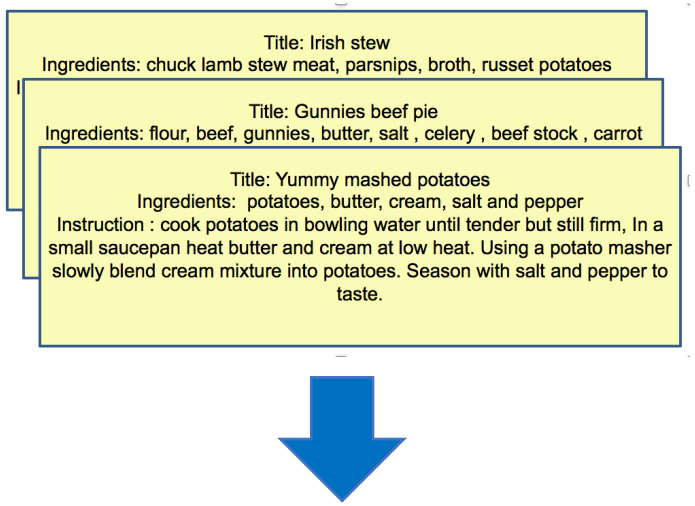
Title: Irish stew

Title: Gunnies beef pie

Title: Yummy mashed potatoes
Ingredients: butter, cream, potatoes salt and pepper
Instruction : cook potatoes in bowling water until tender but still firm, In a small saucepan heat butter and cream at low heat. Using a potato masher slowly blend cream mixture into potatoes. Season with salt and pepper to taste.

Recipe 1, 2, 3

Bag of word representation



	a	in	potatoes	salt	low	saucepan	but			beef			lamb
R1	2	2	4	2	1	1	1			0			0
R2	9	5	0	4	0	4	0			2			0
R3	6	4	3	3	0	2	0			0			3

Recommending recipes

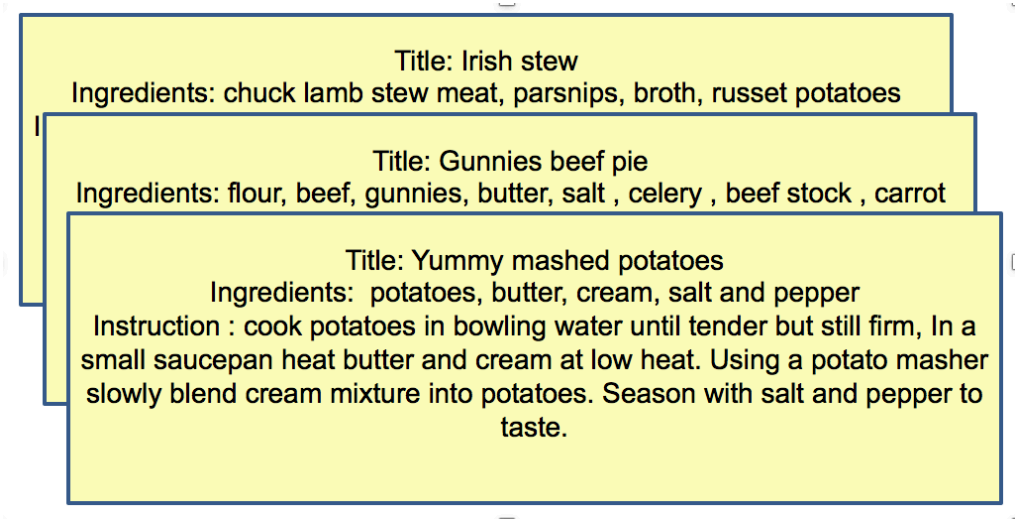
beef recipes

	a	in	potatoes	salt	low	saucepan	but			beef			lamb
R1	2	2	4	2	1	1	1			0			0
R2	9	5	0	4	0	4	0			2			0
R3	6	4	3	3	0	2	0			0			3

Understanding the relevance weight

	a	in	potatoes	salt	low	saucepan	but			beef			lamb
R1	2	2	4	2	1	1	1			0			0
R2	9	5	0	4	0	4	0			2			0
R3	6	4	3	3	0	2	0			0			3

Document Frequency: Occurrence of terms over entire corpus



Terms	Frequency
Potatoes	7
saucepan	7
heat	9
Title	3
.....	
in	11
salt	9
tender	1
a	17

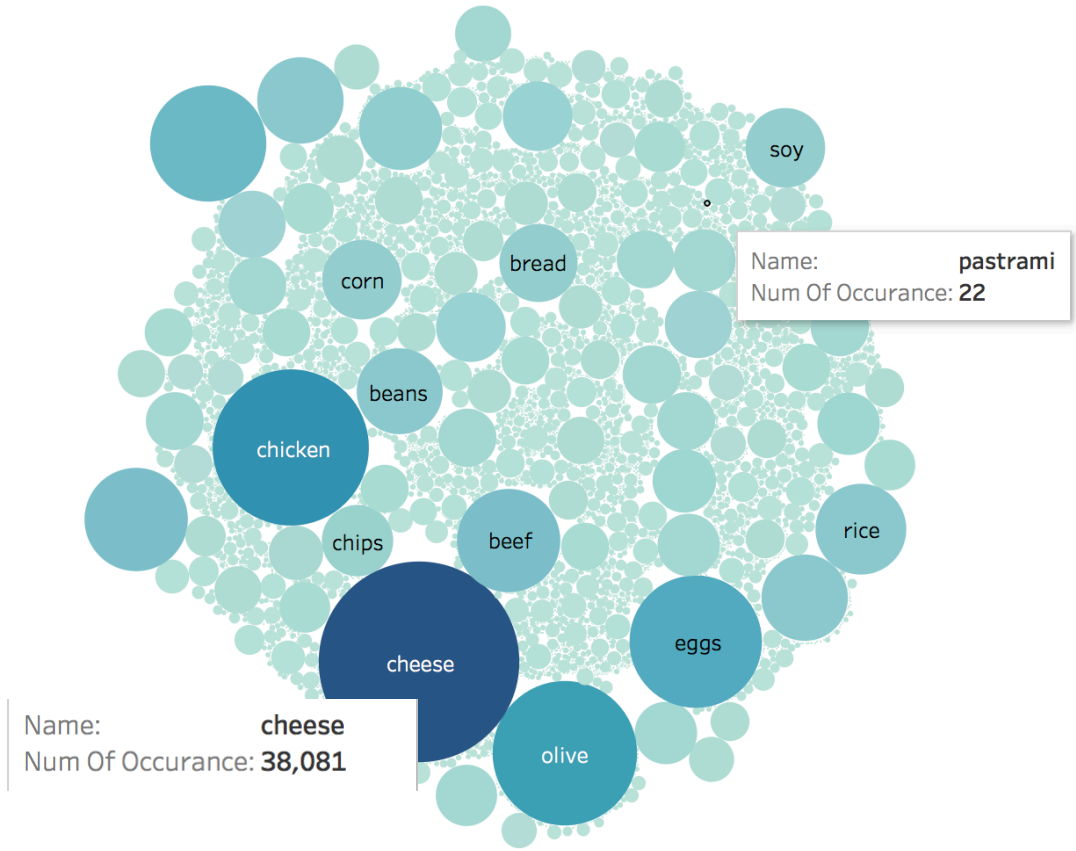
Frequency Matrix

	a	in	potatoes	salt	low	saucepan	but			beef			lamb
R1	2	2	4	2	1	1	1			0			0
R2	9	5	0	4	0	4	0			2			0
R3	6	4	3	3	0	2	0			0			3

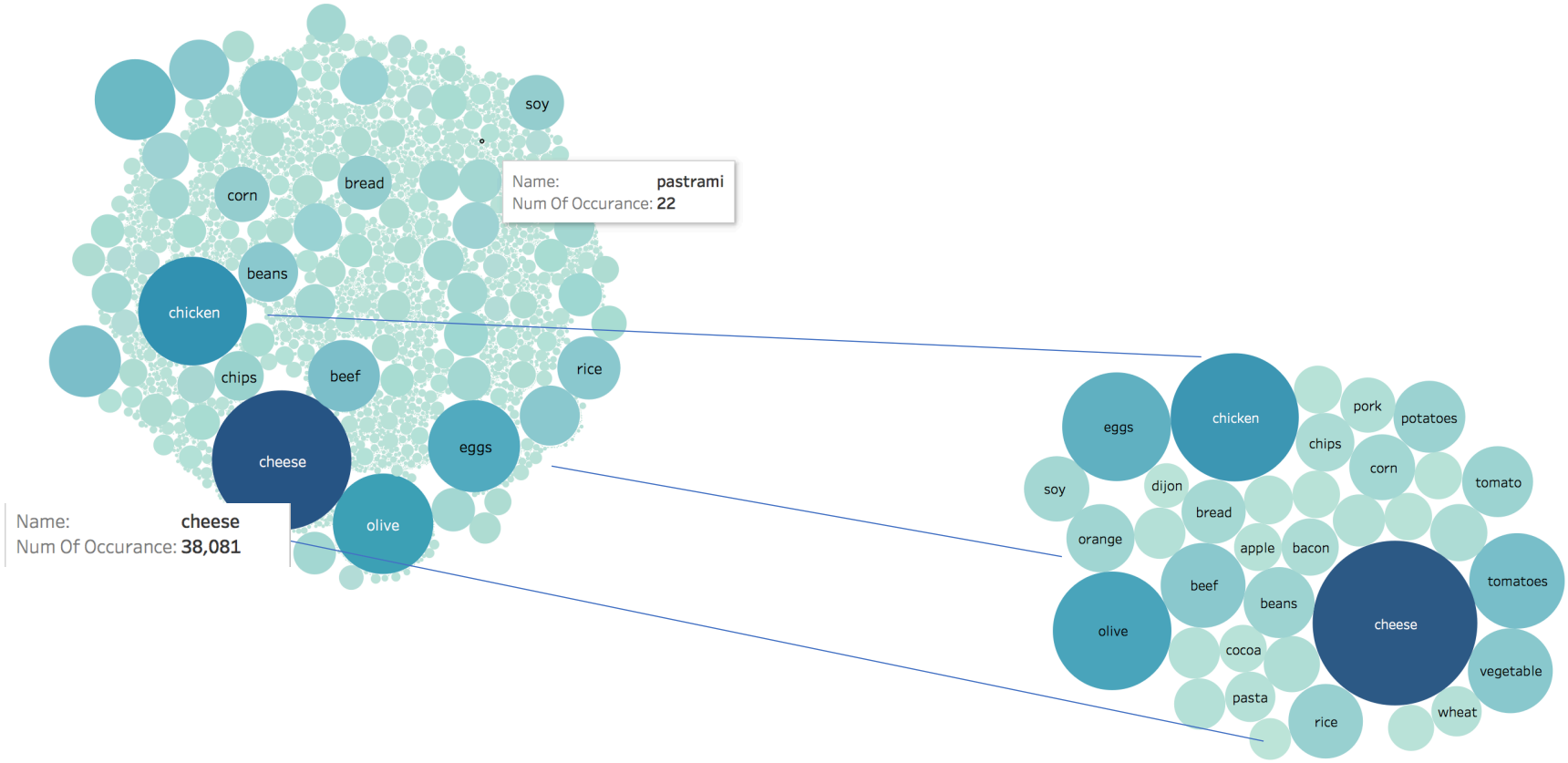
Tf-Idf Matrix

	a	in	potatoes	salt	low	saucepan	but			beef			lamb
R1	0.493	0.871	2.296	1.045	1.477	0.632	1.477	0	0	0	0	0	0
R2	2.220	2.178	0.574	2.091	0	2.528	0	0	0	2.352	0	0	0
R3	1.480	1.742	1.722	1.568	0	1.264	0	0	0	0	0	0	3

- 10,661 ingredients
- 230,872 recipes



Considering only highly frequent ingredients ?



What information are relevant to Food Recommender?

Topic Modeling

Topic models aim to discover the latent semantic structure or themes within a corpus of documents, which can be derived from co-occurrences of words across the documents.

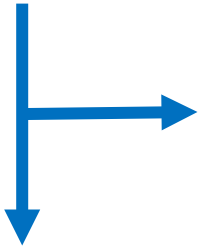
-Mark Belford

Topic Model

A topic model typically consists of k topics, each represented by a ranked list of strongly-associated terms (often referred to as a “topic descriptor”).

	a	in	potatoes	salt	low	saucepan	but	beef	lamb
R1	2	2	4	2	1	1	1	0	0
R2	9	5	0	4	0	4	0	2	0
R3	6	4	3	3	0	2	0	0	3
R4	2	2	4	2	1	1	1	0	0
R5	9	5	0	4	0	4	0	2	0
R6	6	4	3	3	0	2	0	0	3

Topic Modeling



Recipe-Topic Matrix

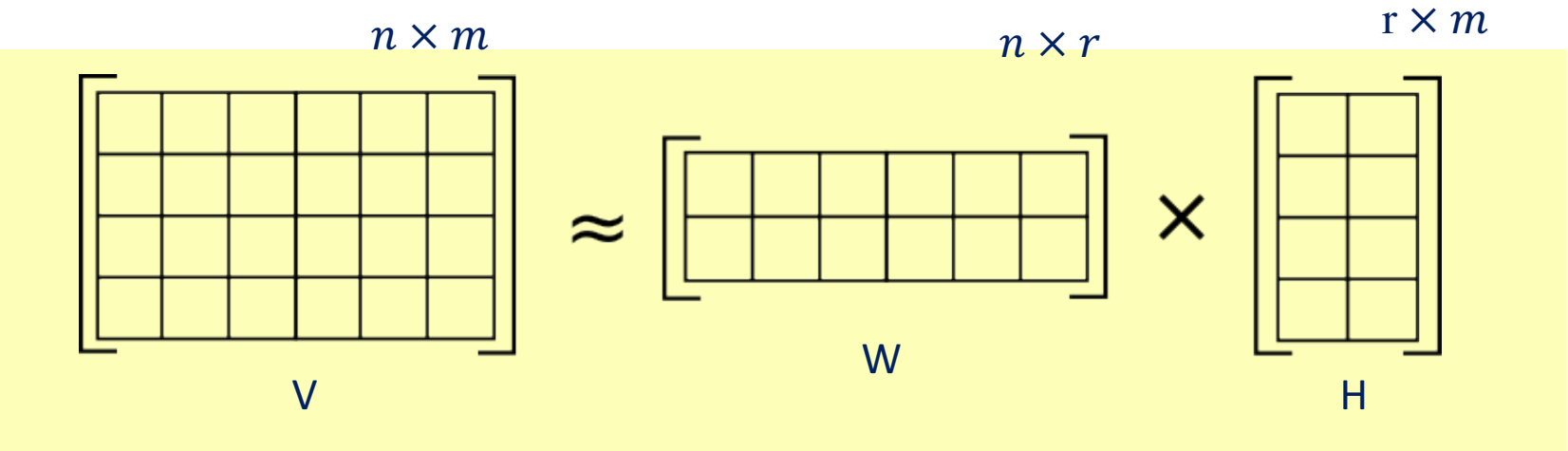
	$Topic_1$	$Topic_2$	$Topic_3$
R_1	.5	0	0
R_2	0	0	0
R_3	.7	0	0.002
R_4	0	0	0
R_5	0	0.3	0.9
R_6	0	0	0

Topic -Term Matrix

	potatoes	saucepan	coco	beef	lamb
$Topic_1$	6	.07	0	7	0
$Topic_2$	6	1	0	0	4
$Topic_3$	0	1	2	0	0

Each document/recipe in the corpus can be associated with one or more topics.

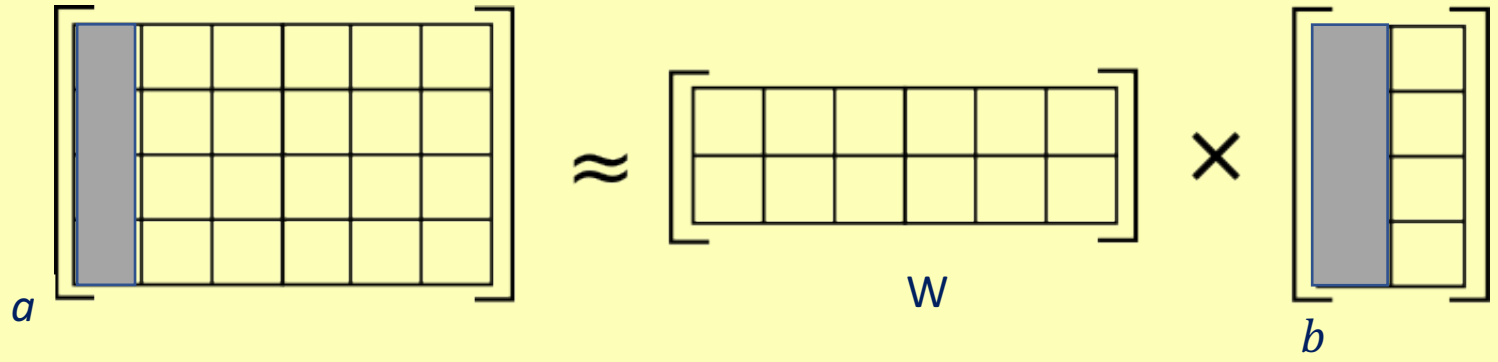
Non- negative matrix factorization



$$V \approx W \times H$$

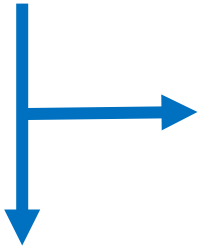
It can be rewritten column by column as,

$$a \sim W \times b$$



	a	in	potatoes	salt	low	saucepan	but	beef	lamb
R1	2	2	4	2	1	1	1	0	0
R2	9	5	0	4	0	4	0	2	0
R3	6	4	3	3	0	2	0	0	3
R4	2	2	4	2	1	1	1	0	0
R5	9	5	0	4	0	4	0	2	0
R6	6	4	3	3	0	2	0	0	3

Topic Modeling



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R_6	0	0	0

Topic -Term Matrix

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$Topic_1$	6	.07	0	7	0
$Topic_2$	6	1	0	0	4
$Topic_3$	0	1	2	0	0

Outcome of different topic modeling session is only approximately equal

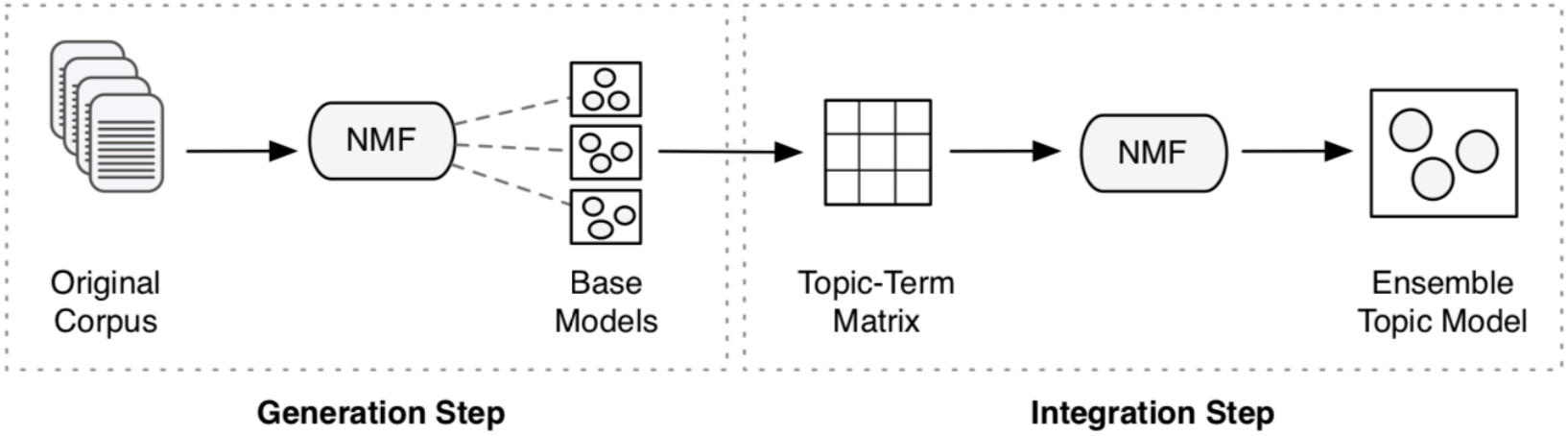
Topic	Terms
Topic 0	beginner-cook, easy, inexpensive, kid-friendly, appetizer, eggs-dairy, holiday-event, snack, toddler-friendly, technique, served-cold, potluck, egg-free, finger-food, european
Topic 1	cheese, eggs-dairy, cheddar, parmesan, appetizer, mozzarella, tortilla, high-calcium, low-carb, cheesecake, macaroni, mayonnaise, feta, goat, lasagna
Topic 2	spinach, olive, feta, artichoke, vegetable, strawberry, parmesan, low-carb, pine, main-dish, salad-dressings, lasagna, tofu, vinaigrette, phyllo
Topic 3	casserole, one-dish-meal, main-dish, sausage, cheddar, noodle, tuna, side-dishes, macaroni, potluck, bubbly, cheese, weeknight, ritz, less-than-half-hour
Topic 4	apple, dessert, low-protein, tart, cranberry, pies-and-tarts, walnut, oat, caramel, applesauce, pecan, maple, pear, batter,salad
Topic 5	dessert, cookies-and-brownies, for-large-groups, cocoa, holiday-event, pecan, almond, bar-cookies, pudding, drop-cookies, christmas, pies-and-tarts, pumpkin, savoury, mixer
Topic 6	vegetable, carrot, side-dishes, zucchini, soups-stews, celery, cabbage, stove-top, asparagus, carrots, cauliflower, pea, pumpkin, mushrooms, green-yellow-beans
Topic 7	corn, tortilla, cornstarch, cornmeal, salsa, cilantro, chowder, cornbread, jalapeno, chilies, cob, ear, popcorn, soups-stews, pecan
Topic 8	rice, side-dishes, soy, white-rice, brown-rice, chinese, basmati, long-grain, pea, one-dish-meal, risotto, pilaf, stove-top, stir-fry, celery
Topic 9	low-cholesterol, low-protein, low-calorie, low-carb, easy, side-dishes, soups-stews, appetizer, strawberry, smoothy, peach, cucumber, technique, savory-sauces, salsa
Topic 10	broccoli, floret, cauliflower, vegetable, mayonnaise, soy, cornstarch, stir-fry, cheddar, chinese, side-dishes, bisques-cream-soups, florets, low-carb, sunflower

Topic	Terms
Topic 0	vegetable, side-dishes, broccoli, spinach, zucchini, asparagus, stove-top, cauliflower, olive, mushrooms, green-yellow-beans, served-hot, soy, beans, cucumber
Topic 1	dessert, cookies-and-brownies, for-large-groups, cocoa, pecan, bar-cookies, holiday-event, drop-cookies, pudding, cooky, walnut, pies-and-tarts, mixer, christmas, hand-formed-cookies
Topic 2	bread, quick-breads, loaf, wheat, rolls-biscuits, low-cholesterol, muffins, small-appliance, for-large-groups, cornmeal, batter, weeknight, high-calcium, coffee-cakes, easy
Topic 3	dessert, apple, low-protein, tart, cranberry, pies-and-tarts, walnut, saur, caramel, applesauce, pecan, maple, pear, batter,salad
Topic 4	chicken, poultry, meat, chicken-breasts, main-dish, low-carb, one-dish-meal, high-protein, chicken-thighs-legs, olive, soy, wing, whole-chicken, easy, weeknight
Topic 5	low-cholesterol, low-protein, low-calorie, low-carb, easy, side-dishes, soups-stews, appetizer, strawberry, smoothy, peach, cucumber, technique, savory-sauces, salsa
Topic 6	beginner-cook, easy, inexpensive, kid-friendly, eggs-dairy, holiday-event, toddler-friendly, snack, technique, served-cold, potluck, egg-free, european, served-hot, south-west-pacific
Topic 7	orange, citrus, cranberry, marmalade, mandarin, holiday-event, tea, oranges, easy, christmas, served-cold, olive, apricot, eel, grapefruit
Topic 8	banana, tropical-fruit, bananas, quick-breads, smoothy, yogurt, muffins, smoothie, walnut, pudding, kid-friendly, wheat, oat, blueberry, batter
Topic 9	almond, blueberry, cherry, raspberry, almonds, peach, coffee, pitted-fruit, yogurt, batter, apricot, yolk, cranberry, european, maraschino
Topic 10	tortilla, appetizer, salsa, cilantro, avocado, jalapeno, mayonnaise, for-large-groups, lettuce, chilies, finger-food, snack, easy, olive, chips

Ensemble Topic Modeling

Ensemble procedures seek to encourage diversity with a view to improving the quality of the information available in the integration phase

- Alexander Topchy



Recipe Recommendation Reasoning on Features : Ensemble Topic Modeling Based Approach

Extracting significant Features(words) using Ensemble Topic modeling

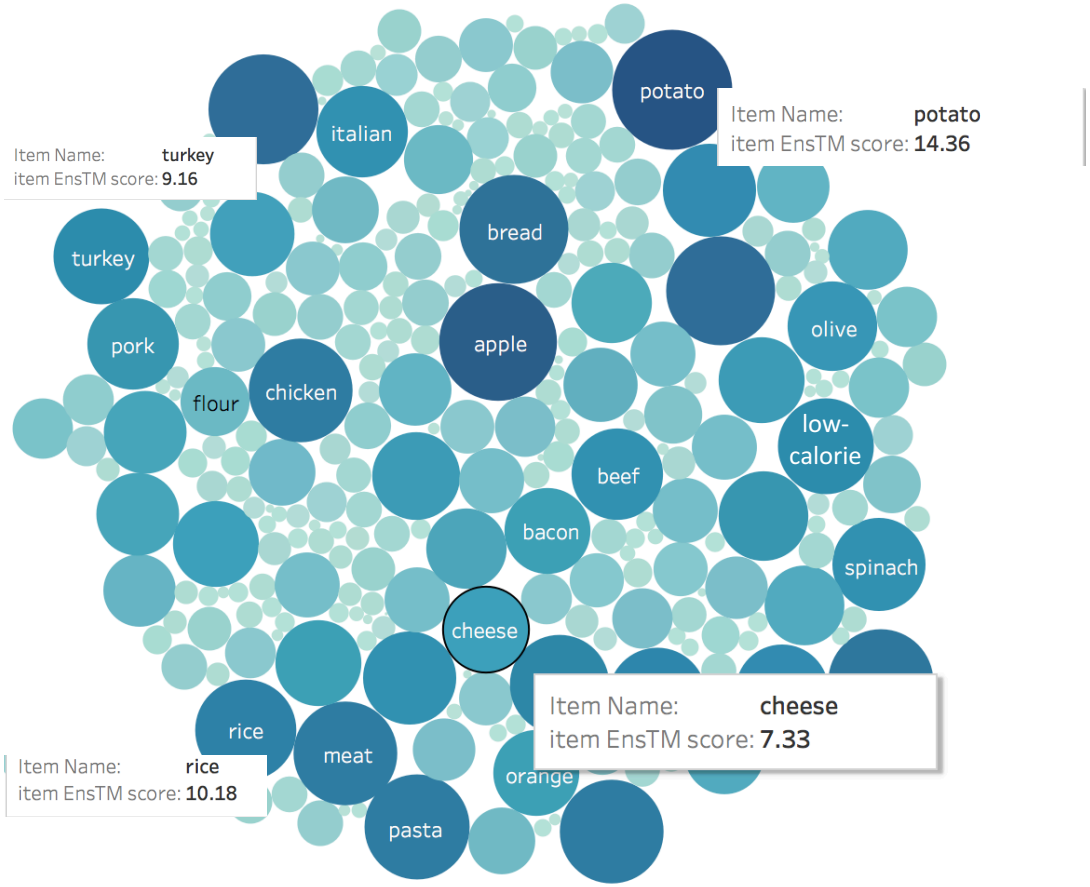
- Tokenize , Lemmatize, Stem , customWord
- Domain and corpus specific Stopwords generation
- Ensemble Topic modeling
- Selecting first 15 words from top 30 topics
- Calculating the weight for the Unique 288 words from the previous step

Example of identified topics

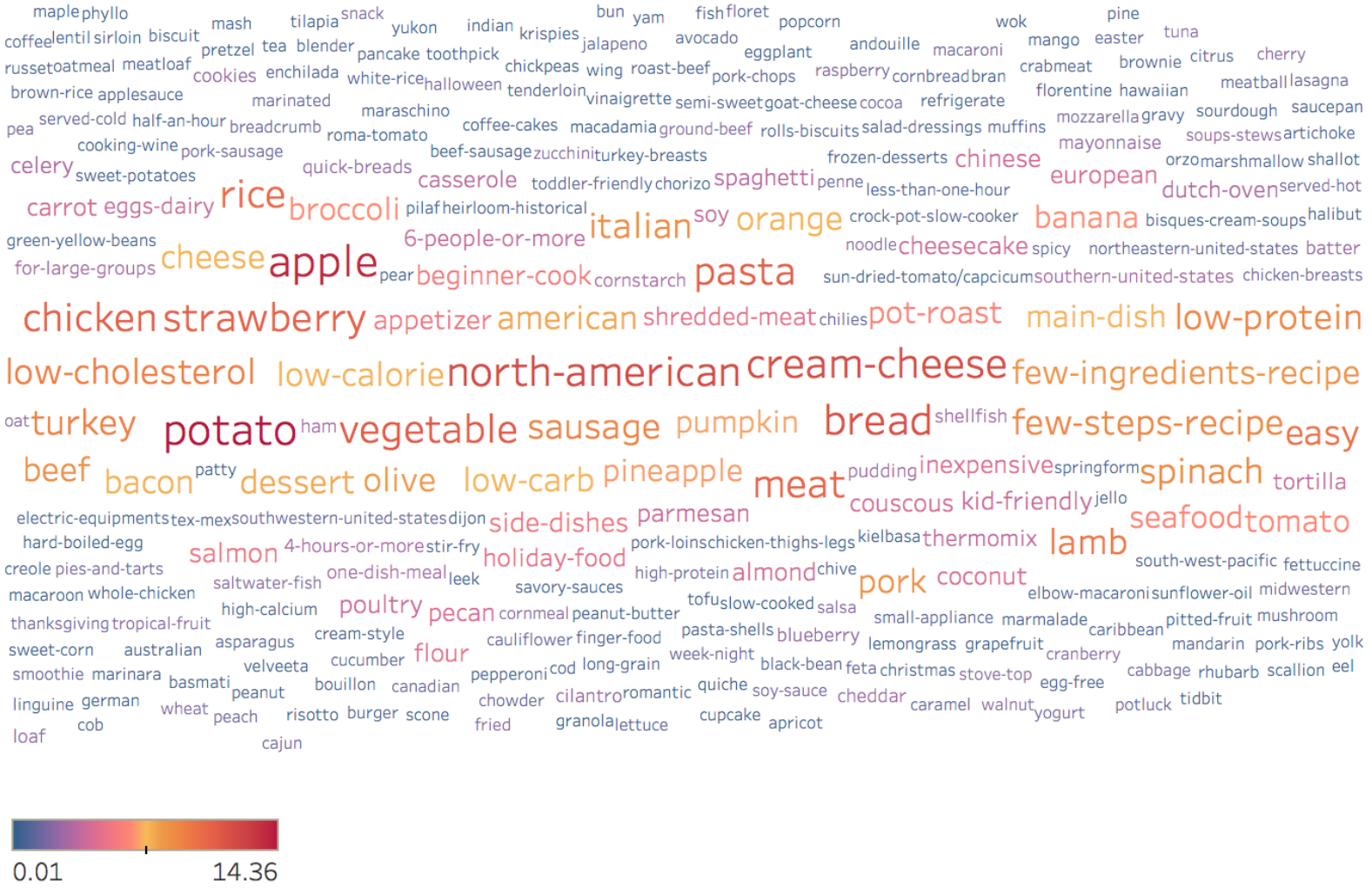
Topics discriptor	List of 15 features within each topic
Roman	italian, beef-sausage, european, olive, parmesan, mozzarella, pork-sausage, spaghetti, chorizo, pepperoni, lasagna, german, marinara, eggplant, romantic
Banana based dessert and drinks	banana, tropical-fruit, frozen-desserts, quick-breads, smoothie, yogurt, muffins, thermomix, walnut, blueberry, pudding, krispies, wheat, bran, batter
Easy and quick snacks	beginner-cook, easy, inexpensive, kid-friendly, appetizer, eggs-dairy, holiday-food, pretzel, toddler-friendly, few-ingredients-recipe, served-cold, potluck, egg-free, finger-food, served-hot
Easy fish mains	salmon, fish, saltwater-fish, seafood, main-dish, high-protein, spinach, low-carb, vinaigrette, cream-cheese, halibut, dijon, asparagus, chickpeas, beginner-cook
Corn based maxican	tortilla, cornstarch, cornmeal, casserole, salsa, chowder, cornbread, cilantro, jalapeno, chilies, cob, sweet-corn, popcorn, soups-stews, roma-tomato
Rice dishes	rice, side-dishes, white-rice, soy, casserole, brown-rice, chinese, one-dish-meal, basmati, long-grain, pea, risotto, pilaf, stir-fry, stove-top
Tropical juice and desserts	pineapple, tropical-fruit, cherry, hawaiian, mango, maraschino, carrot, low-protein, cornstarch, dessert, soy, pudding, marshmallow, easy, caribbean
Beef based mains	beef, meat, ground-beef, main-dish, one-dish-meal, roast-beef, sirloin, crock-pot-slow-cooker, meatloaf, casserole, meatball, scallion, noodle, breadcrumb, easy
Vegetable dishes	vegetable, carrot, saucepan, zucchini, spinach, soups-stews, tofu, cabbage, sunflower-oil, asparagus, week-night, chickpeas, cauliflower, hard-boiled-egg, mushroom
Seafood mains	seafood, soy-sauce, shellfish, tuna, appetizer, main-dish, wok, low-carb, leek, crabmeat, olive, cod,high-protein, easy, cream-style
Turkey mains	turkey, meat, cooking-wine, main-dish, couscous, thanksgiving, turkey-breasts, tortilla, sausage, lettuce, cranberry, one-dish-meal, burger, gravy, casserole
Health conscious	low-cholesterol, low-protein, low-calorie, ow-carb, easy, side-dishes, soups-stews, appetizer, smoothie, few-steps-recipe, cucumber, egg-free, savory- -appliance, salsa

The final 288 Food Features

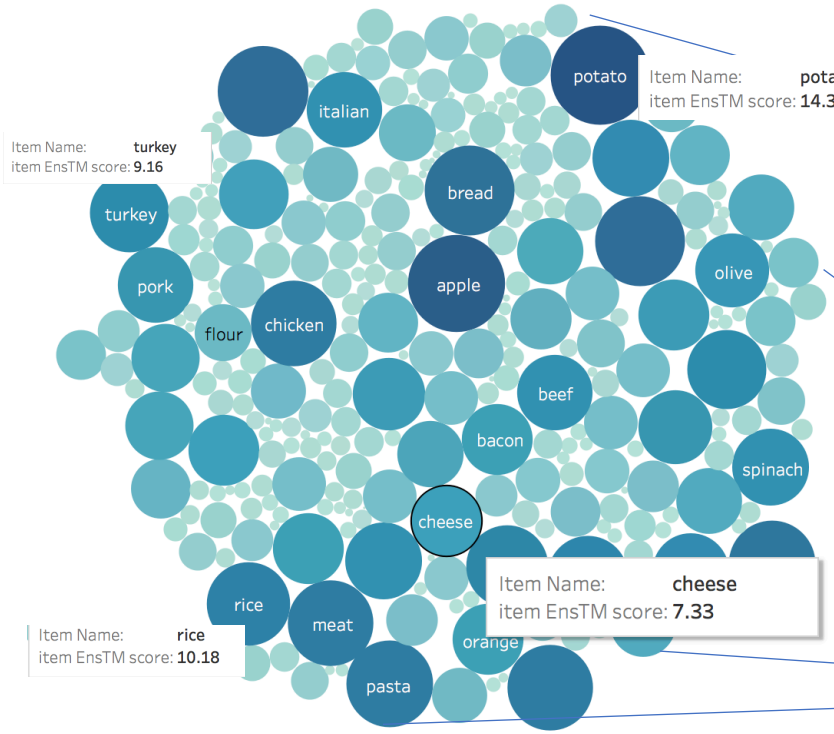
Which we later considered the basis of new data representation format and thereby recommendation algorithms



The final 288 Food Features



The final 288 Food Features



	%	Features
context	4.2	holiday-food, beginner-cook, week-night, inexpensive , 6-people-or-more, potluck
cuisine	6.7	italian, hawaiian, tex-mex, chinese, cajun
equipment	2.4	saucepan, thermomix, wok, dutch-oven
cooking process	3.12	few-steps-recipe, less-than-one-hour, fried, slow-cooked, marinated, 4-hours-or-more
ingredient	61.15	poultry, feta, spaghetti, shredded-mea
category	15.2	risotto, lasagna, stew, appetizer, pot-roast
nutrition	3.01	high-calcium, low-cholesterol, egg-free

Our proposed n-by-288 data representation format

Recipes	*Plaintext*
R_1	$Document_1$
R_2	$Document_2$
.	.....
R_n	$Document_n$

$\xrightarrow{EnsTM}$

	f_1	f_2	.	.	f_{288}
R_1	0.79	0	.	.	.31
R_2	0	0	.	.	0
.	.	.	.	.	.
R_n	0.61	1	.	.	.08

Recommendation approaches

Food Features based Recommendation (FFbR)

- u_a is an user
- r_n is a new recipe
- i is each feature in r_n i=0,1,2....m
- $f_{i,ua}$ is u_a's rating on i

$$P(u_a, r_n) = \left(\sum_{i=0}^{m} f_{i,u_a} \right)'(0,5)$$

Recommendation approaches

Weighted Food Features based Recommendation (WFFbR)

- u_a is an user
- r_n is a new recipe
- i is each ingredient in r_n i=0,1,2....m
- $f_{i,ua}$ is u_a's rating on i
- w_i is significance score of each feature

$$P(u_a, r_n) = \left(\sum_{i=0}^{m} f_{i,u_a} \times w_i \right)^{\prime(0,5)}$$

Recommendation approaches

Food Features based Collaborative Filtering (FFbCF)

$$P(f_{b,u_a}) = \frac{\sum_{i=0}^{n} f_{b,i}}{n}$$

- u_a is an user
- i is each neighbor of u_a i=0,1,2....n
- $f_{b,i}$ is neighbor i's rating on a feature f_b
- We calculate $f_{r,ua}$ using FFbR after learning u_a's rating on all unknown feature f_b using FFbCF

Recommendation approaches

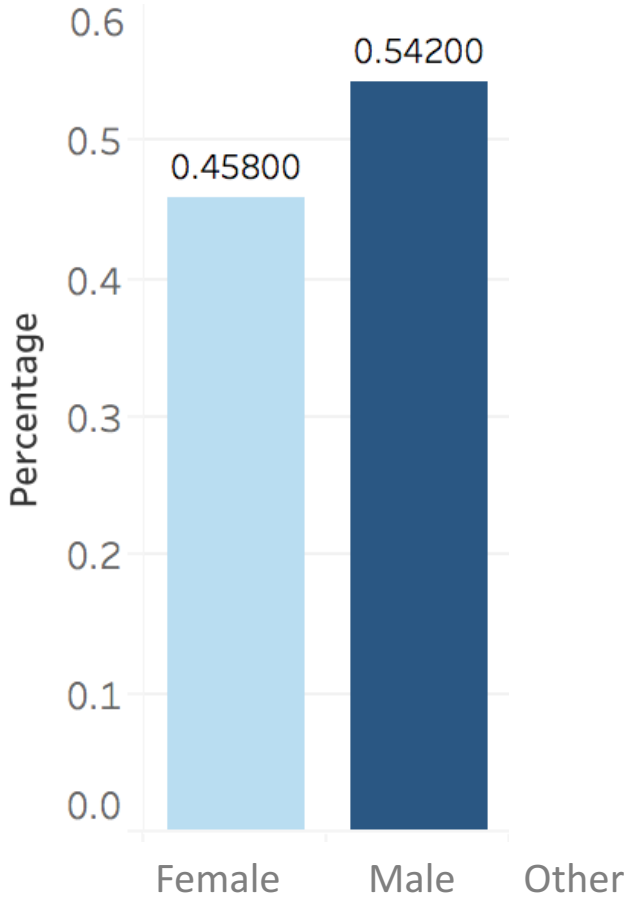
Content Based(CB)

$$P(u_a, r_n) = \frac{\sum_{i=0}^{m} Ing_{i,u_a}}{m}$$

- u_a is an user
- r_n is a new recipe
- i is each ingredient in r_n i=0,1,2....m
- $Ing_{i,ua}$ is u_a's rating on i

User modeling and testing the recommendation algorithms

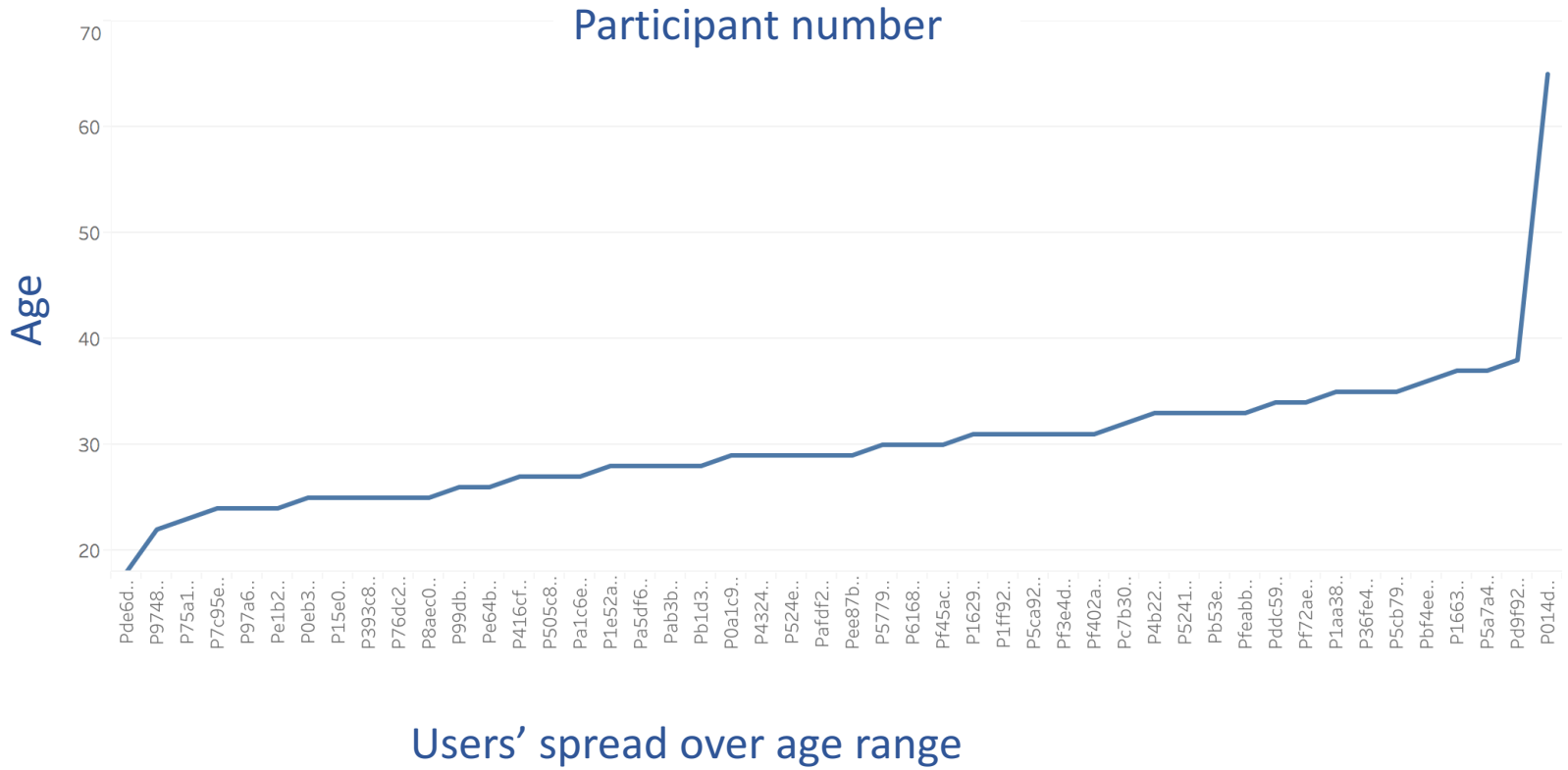
User Study : 4 recommenders and 48 user



Users' spread over gender category

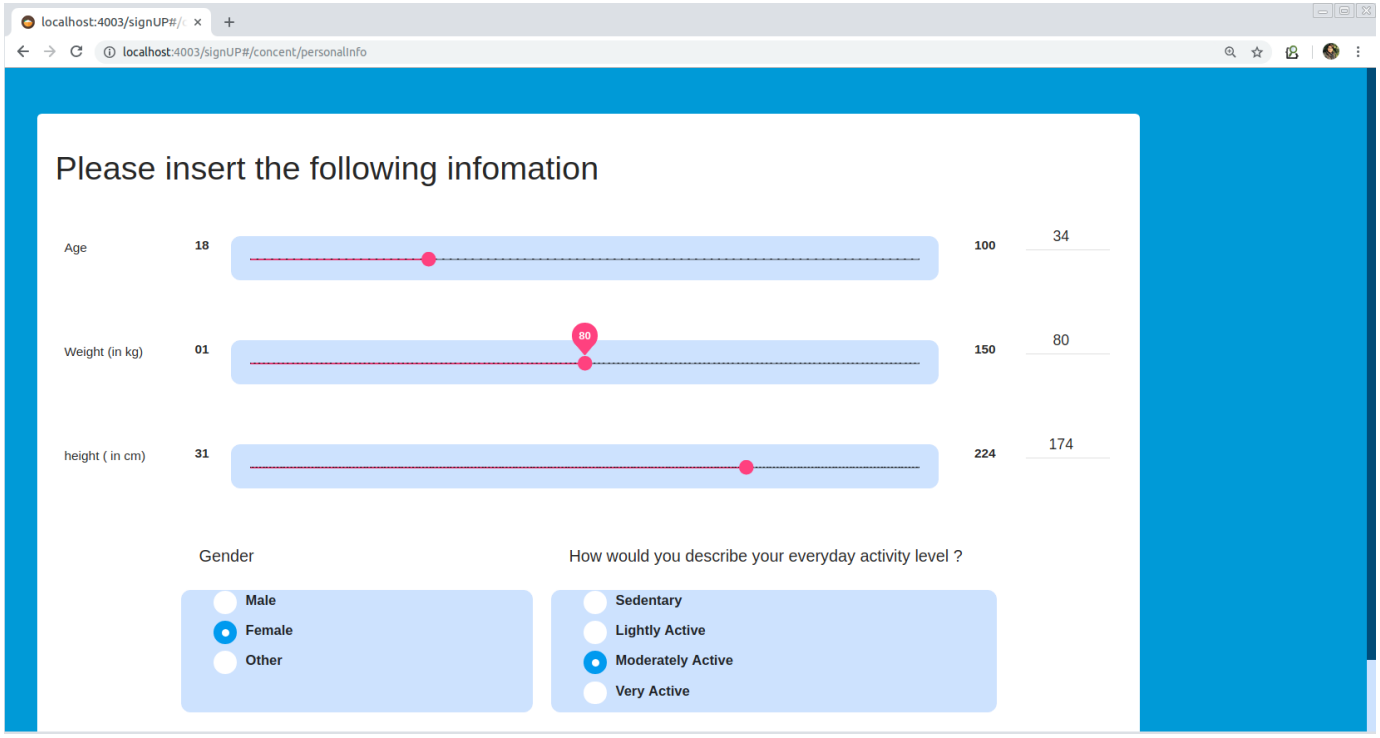
Users' spread over activity category

User Study : 4 recommenders and 48 user

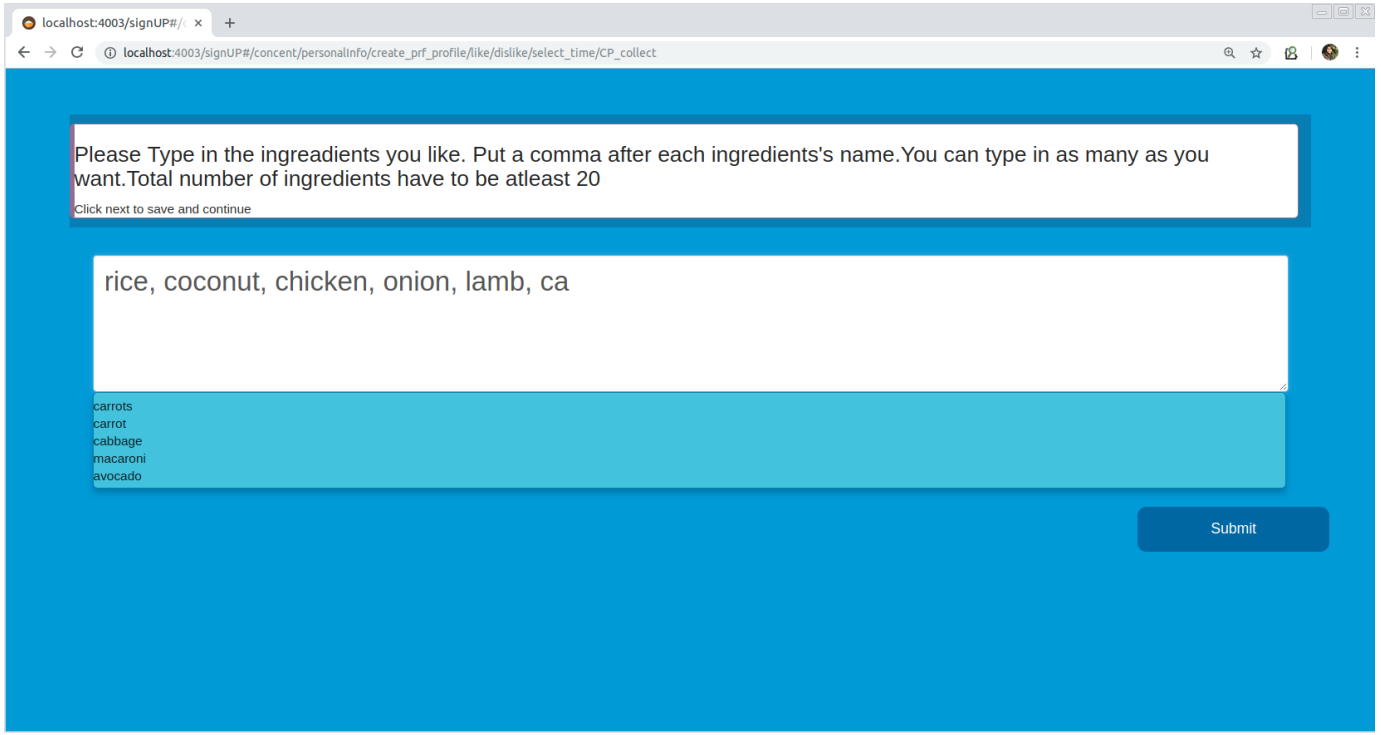


Users' spread over age range

User Study : 4 recommenders and 48 user



User Study : 4 recommenders and 48 user



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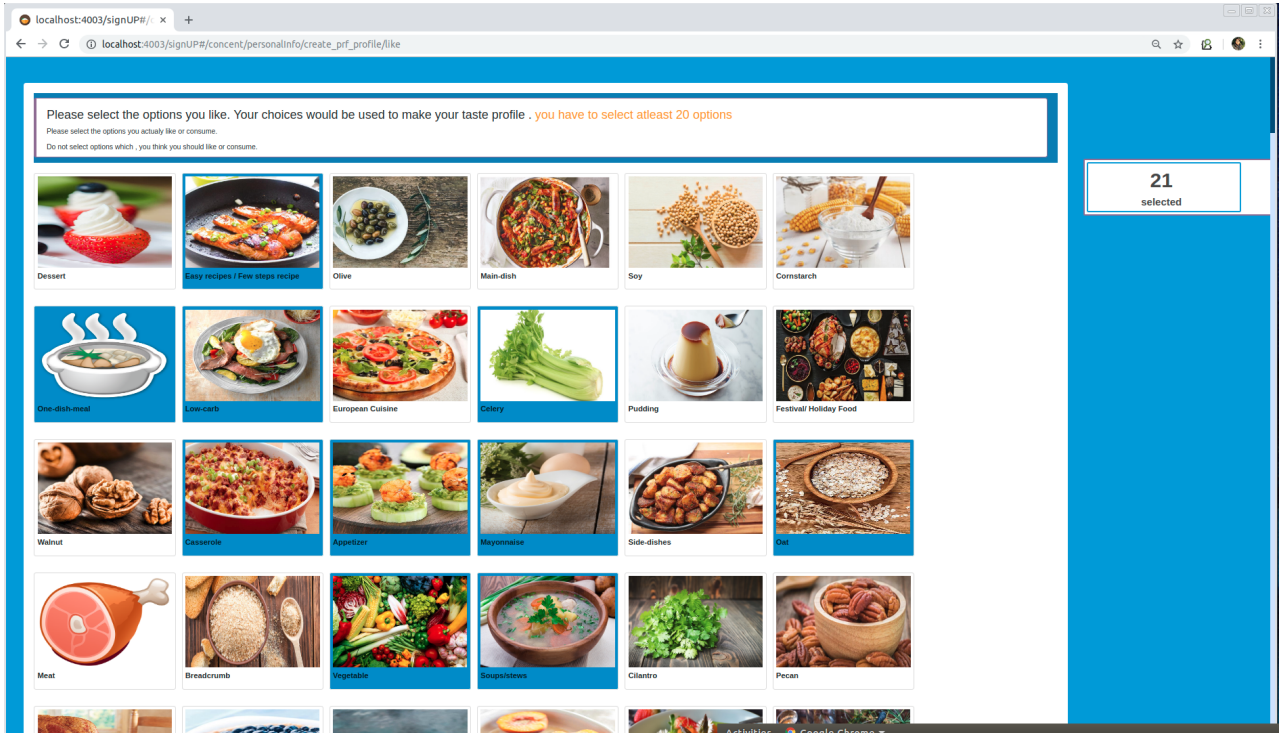
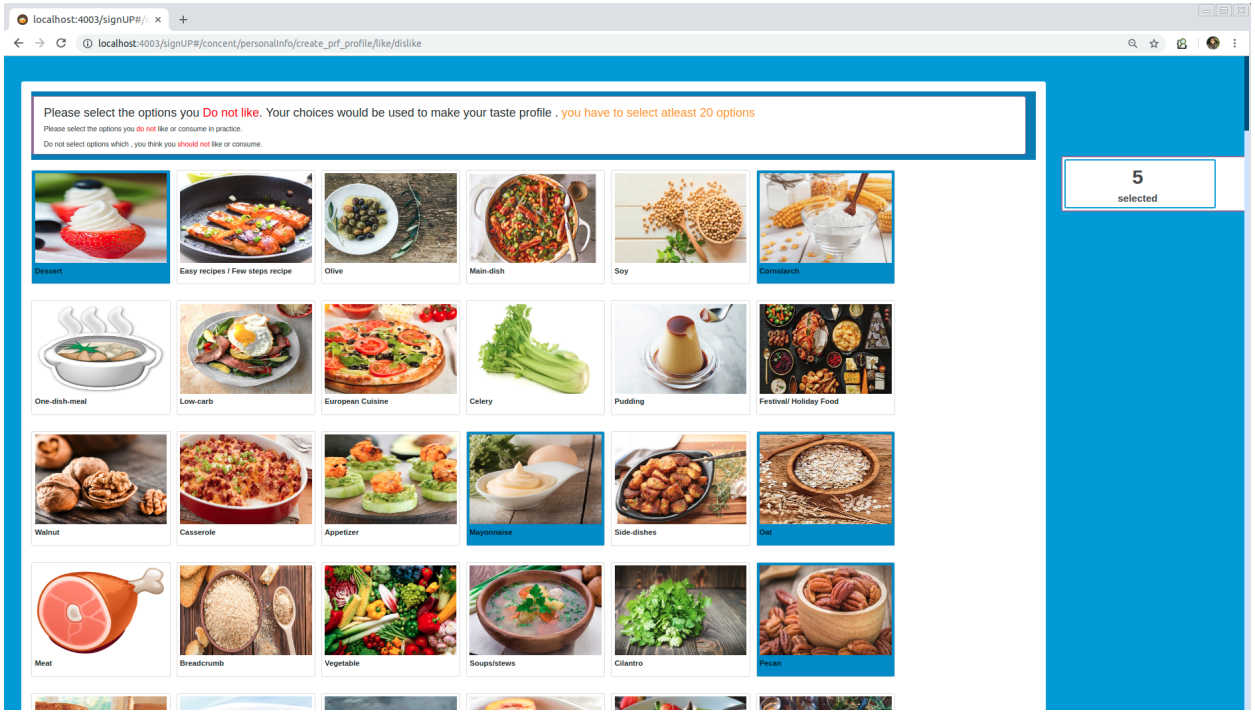
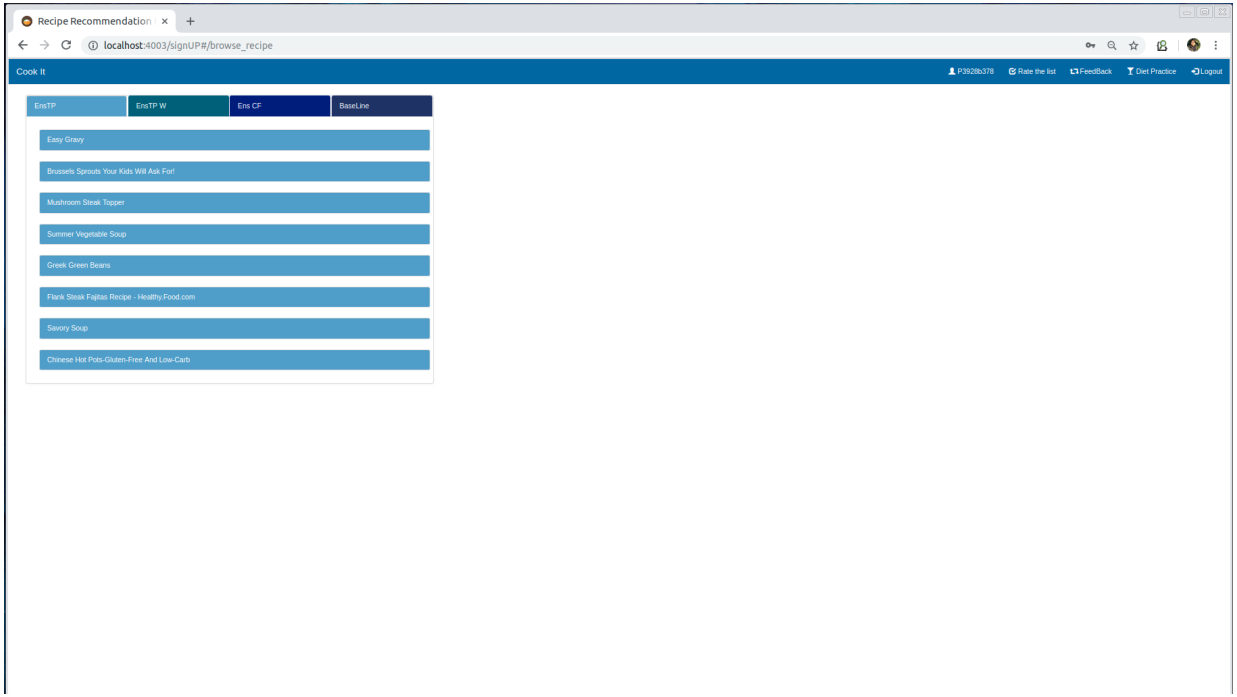


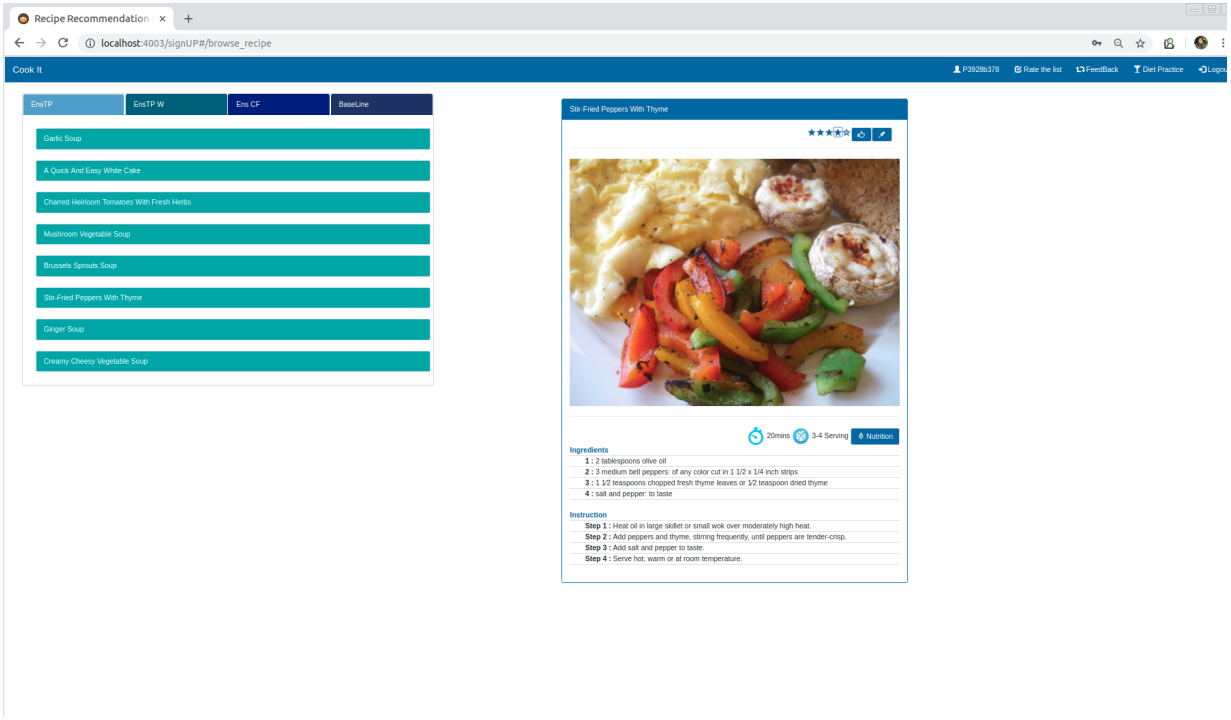
User Study : 4 recommenders and 48 user



User Study : 4 recommenders and 48 user



User Study : 4 recommenders and 48 user



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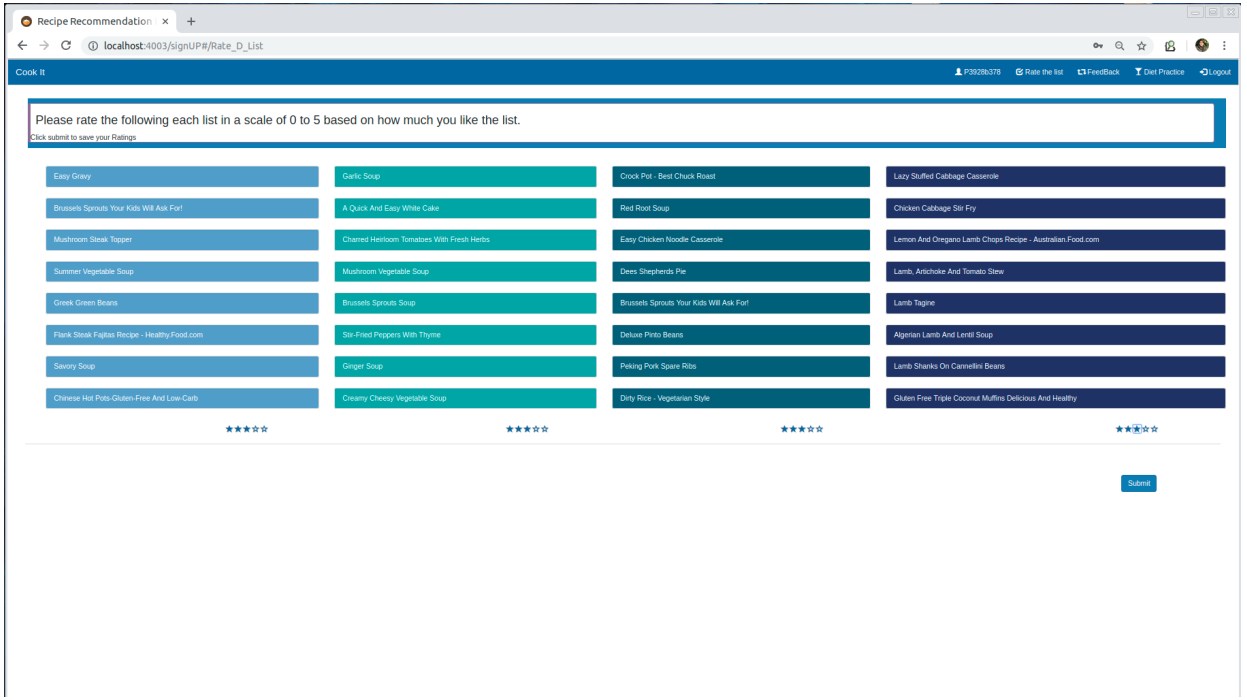
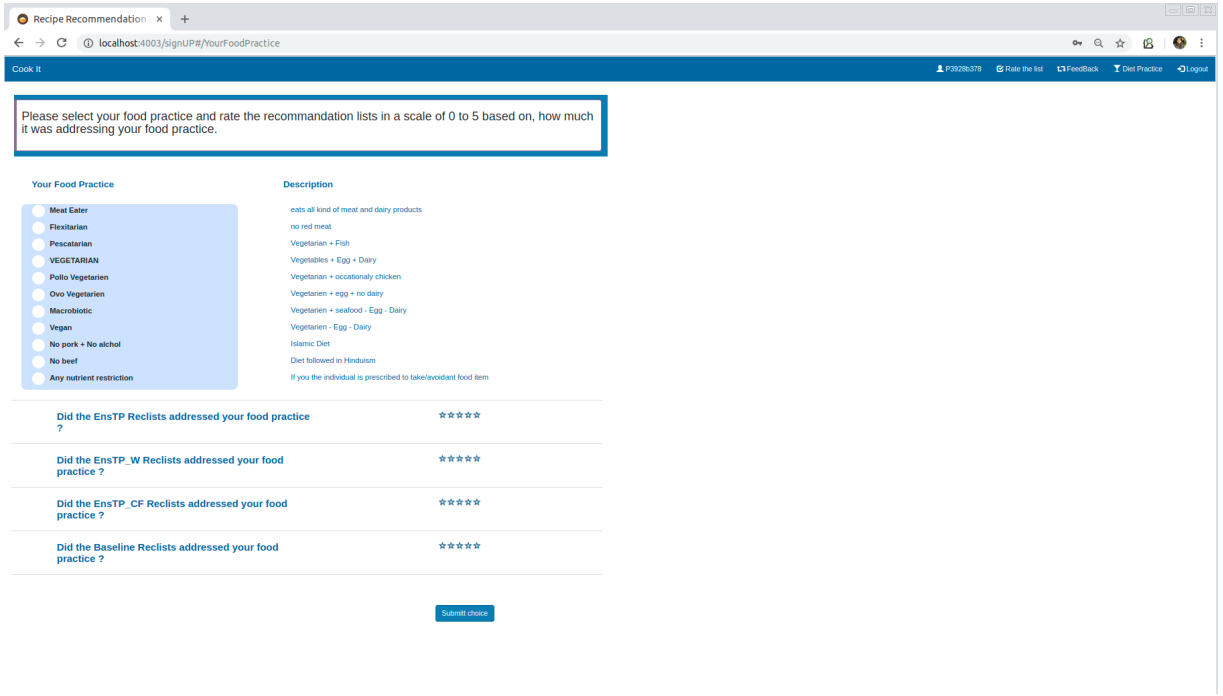


User Study : 4 recommenders and 48 user



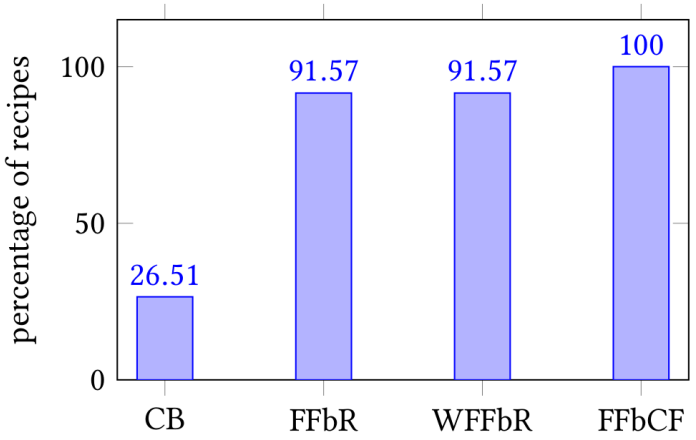
User Study : 4 recommenders and 48 user

Demo on our developed system could be found on

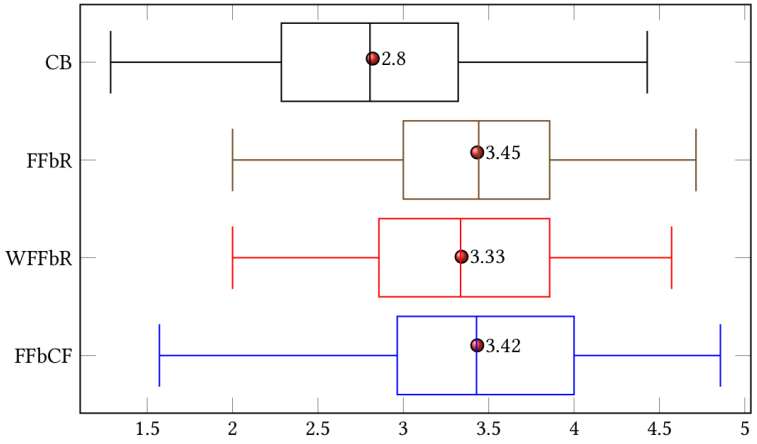
https://www.youtube.com/watch?v=ujaB0FiqRwk

Results

Coverage



User preference



Results

Identifying user's food requirement and restriction

Recommending Healthy Recipe ??

Distributions of items(recipes)in my data-set over WHO and FSA Health Scales.

	Total (percentage)		Total (percentage)
WHO score	Recipes n =230872	FSA score	Recipes n =230872
0	88(.04)	**4**	40877(17.71)
1	2732(1.18)	**5**	32227(13.96)
2	15603(6.76)	**6**	44807(19.41)
3	63969(27.71)	**7**	40647(17.61)
4	123453(53.47)	**8**	30754(13.32)
5	22395(9.7)	**9**	24249(10.5)
6	2533(1.1)	**10**	13002(5.63)
7	99(0.04)	**11**	4009(1.74)
8	0(0)	**12**	300(0.13)

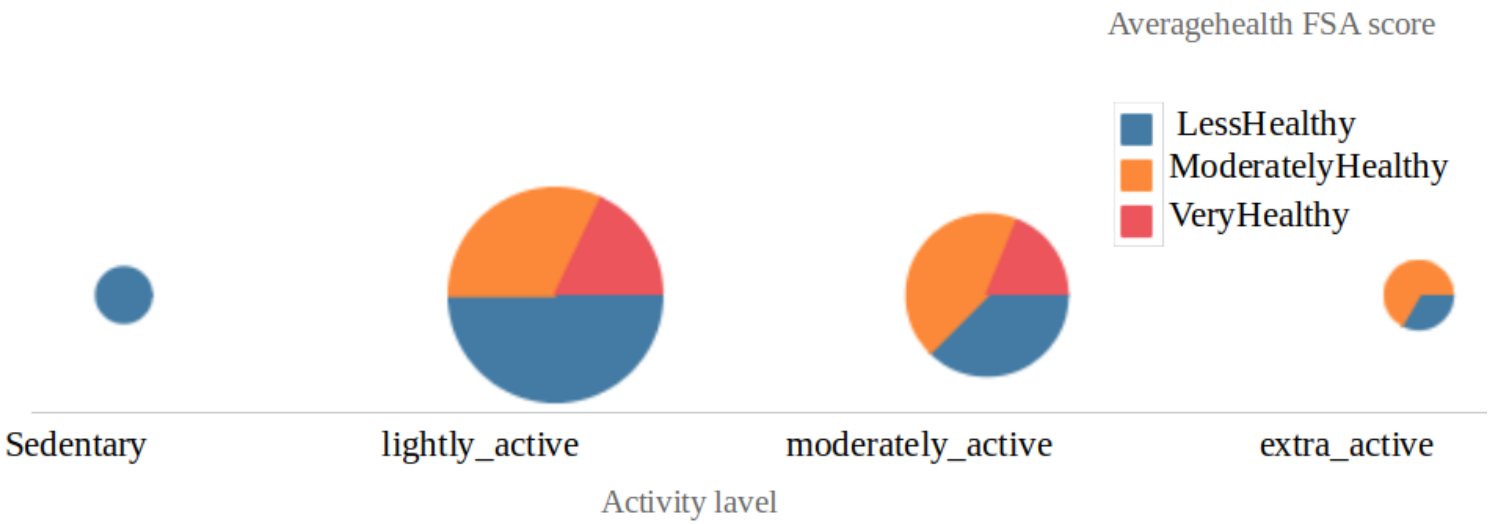
Recommending Healthy Recipe ??

	%	Features
context	4.2	holiday-food, beginner-cook, week-night, inexpensive , 6-people-or-more, potluck
cuisine	6.7	italian, hawaiian, tex-mex, chinese, cajun
equipment	2.4	saucepan, thermomix, wok, dutch-oven
cooking process	3.12	few-steps-recipe, less-than-one-hour, fried, slow-cooked, marinated, 4-hours-or-more
ingredient	61.15	poultry, feta, spaghetti, shredded-mea
category	15.2	risotto, lasagna, stew, appetizer, pot-roast
nutrition	3.01	high-calcium, low-cholesterol, egg-free

Looking for user group with healthier life style??

Scale	Guideline	User Group
Activity Level	FAO: activity level	sedentary, lightly_active, moderately_active, extra_active
BMI	WHO:BMI	underweight, normal_weight , pre_obesity, obesityclass_1
Food Choices	FSA: nutrient intake guideline	less_healthy, moderately_healthy, very_healthy

Looking for user group with healthier life style??



Users' spread over different Healthiness scale

Positively correlated features to healthier user groups

Average Food HealthScore		Activity Level	
Feature	r	Feature	r
peanut-butter	0.447989	wing	0.441152
granola	0.365171	tuna	0.430467
lentil	0.360767	tilapia	0.363502
indian	0.356347	salmon	0.359852
cauliflower	0.352353	hawaiian	0.346401
low-cholesterol	0.350818	canadian	0.322470
maple	0.321131	smoothy	0.314174
vegetable	0.307459	chicken-thighs-legs	0.314059
wheat	0.303326	halibut	0.310990
carrot	0.303052	main-dish	0.303345

Negatively correlated features to healthier user groups

Average Food HealthScore		Activity Level	
	r		r
roast-beef	-0.564273476	hard-boiled	-0.345550067
lasagna	-0.464811126	chicken-breasts	-0.329366275
sausage	-0.389612531	white-rice	-0.32198579
wing	-0.364559511	rice	-0.32198579
thanksgiving	-0.350745293	ham	-0.289471946
chicken-breast	-0.329366275	pear	-0.292700772

Limitation

Feature work

Centre for
Data Analytics

Insight

Thank You

DCU

NUI Galway
OÉ Gaillimh

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

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