An Advanced Recipe Recommendation System

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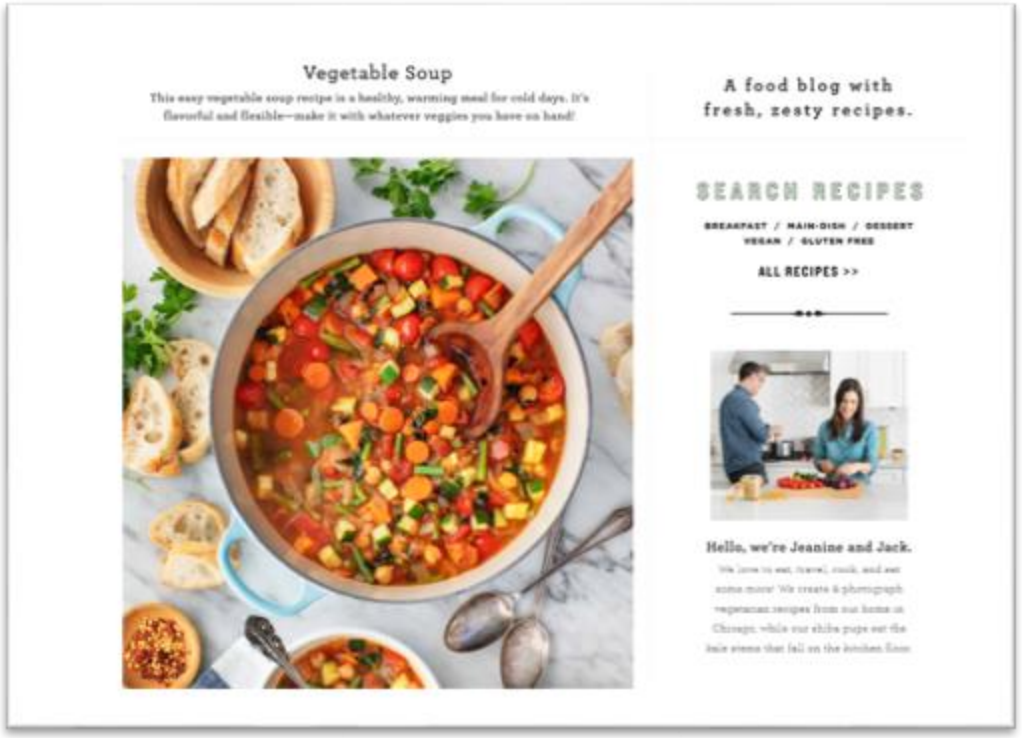
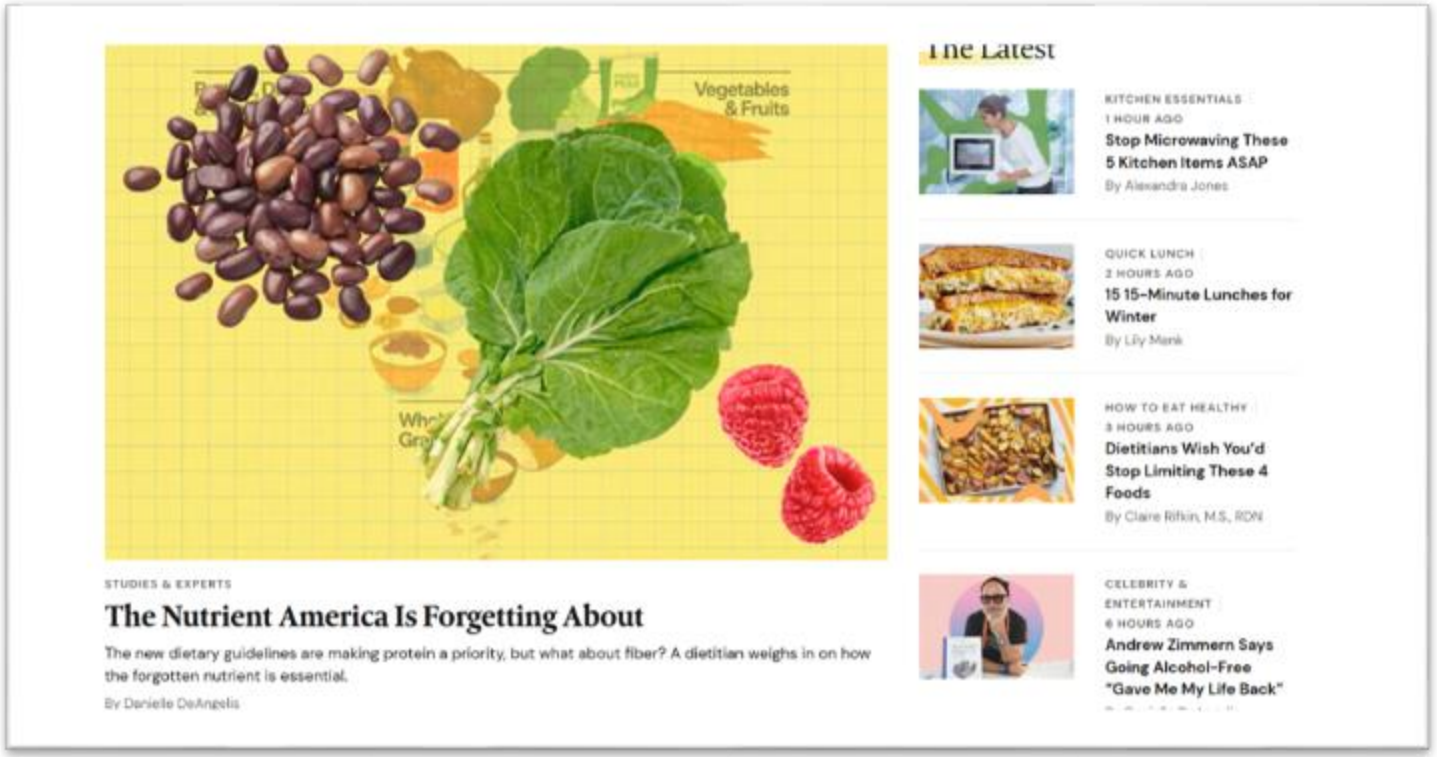
Group 7

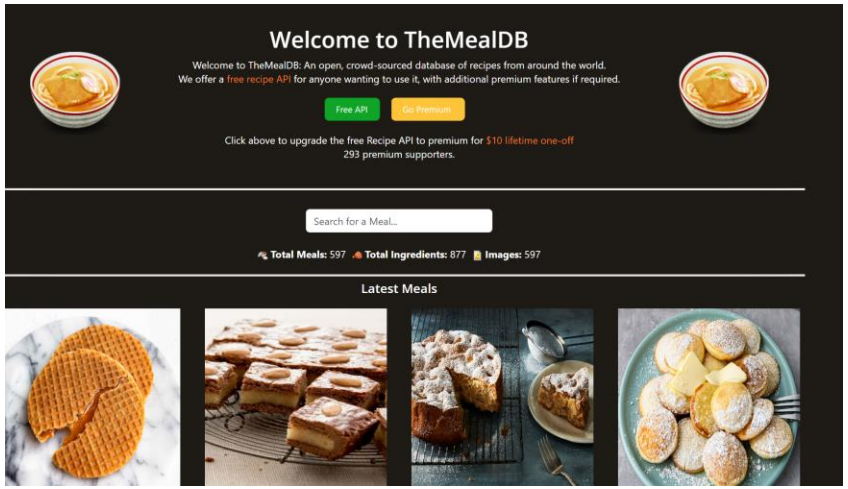
Finding the Right Recipes Is Difficult and Time-Consuming





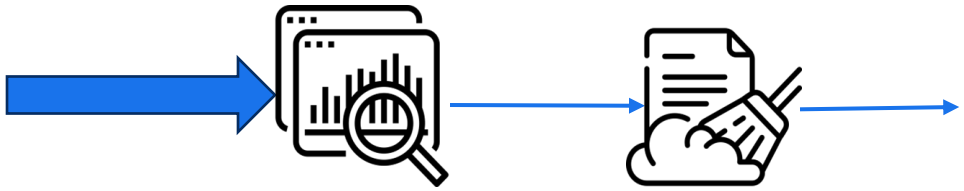
SOURCES: HTTPS://WWW.EATINGWELL.COM/
HTTPS://WWW.LOVEANDLEMONS.COM/

Data Collection & Cleaning



USDA U.S. DEPARTMENT OF AGRICULTURE
Agricultural Research Service

spoonacular API



Recipes
Ingredients
Nutritional
Information

RecipeNLG: A Cooking Recipes Dataset for Semi-Structured Text Generation

RecipeNLG Dataset

- 2 million recipes scraped from the web, initially designed for neural recipe generation, but can accommodate knowledge graph queries easily
- we distinguished a relational model for recipes and their ingredients where one recipe has many ingredients along with their instructions and other related fields
- we integrated food ontology owl dcterms and schema namespaces to associate entities

Spoonacular API

Why This Source

Nutritional Information

Calories, protiens, fat, carbohydrates

Structured Data

JSON data, easy to Transform

Dietery Labels

Vegan, Gluten-free, Vegtarian

Cuisine Classifications

Asian, Italian, Mexican etc.,

RDF

Implementation Details:

- Using Python RDFlib library
- Data stored in Turtle format
- Ontologies used:
- **`schema.org`** (Recipe, Nutrition)
- **`FOOD ontology`** (Ingredients)
- Custom namespaces

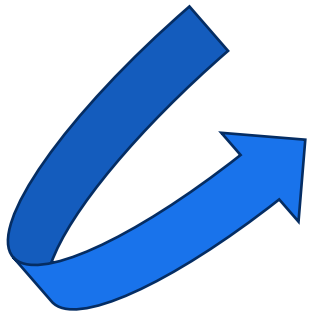
```
<http://example.org/food/recipe/52903> a schema:Recipe ;
    schema:image <https://www.themealdb.com/images/media/meals/xvrrux1511783685.jpg> ;
    schema:keywords "Soup" ;
    schema:name "French Onion Soup" ;
    schema:nutrition <http://example.org/food/nutrition/52903> ;
    schema:recipeCategory "Side" ;
    schema:recipeCuisine "French" ;
    schema:recipeIngredient "1 kg Onion",
        "1 tbs Olive Oil",
        "1 tsp  Sugar",
        "140g Gruyère",
        "1L Beef Stock",
        "2 tbs Plain Flour",
        "250ml Dry White Wine",
        "4 sliced Bread",
        "4 sliced Garlic Clove",
        "50g Butter" ;
    schema:recipeInstructions """Melt the butter with the oil in a large heavy-based pan. Add the onions and fry with the lid on for 10
Add the garlic for the final few mins of the onions' cooking time, then sprinkle in the flour and stir well. Increase the heat and keep
    schema:recipeYield 3 ;
    schema:url <https://www.bbcgoodfood.com/recipes/3020694/french-onion-soup> ;
    schema:video <https://www.youtube.com/watch?v=-DLDMQucqDI> .
```

Ontology

```
ex:hasNutrition rdf:type owl:ObjectProperty ;
    rdf:type owl:FunctionalProperty ;
    rdfs:domain food:Ingredient ;
    rdfs:range schema:NutritionInformation .

ex:ingredientUsage rdf:type owl:ObjectProperty ;
    rdfs:domain schema:Recipe ;
    rdfs:range ex:IngredientUsage .

ex:usesIngredient rdf:type owl:ObjectProperty ;
    rdfs:domain ex:IngredientUsage ;
    rdfs:range food:Ingredient ;
    owl:inverseOf ex:isIngredientOf .

ex:hasIngredient rdf:type owl:ObjectProperty ;
    rdfs:domain schema:Recipe ;
    rdfs:range food:Ingredient ;
    owl:inverseOf ex:isIngredientOf .
```

SPARQL: Basic Filter Search

```
 Advanced Recipe Recommender

Ingredients to AVOID (comma-separated, e.g., nuts, egg): nuts
Ingredients you MUST HAVE (comma-separated, e.g., salmon): chicken
Dietary preferences (e.g., Vegan, Gluten-Free): Gluten-Free
Maximum calories (or press Enter to skip):
Minimum protein in grams (or press Enter to skip):
Your pantry ingredients (comma-separated, optional):

Searching for recipes...
```



```
--- Executing Count SPARQL Query ---

        PREFIX schema: <https://schema.org/>
        SELECT (COUNT(DISTINCT ?recipe) AS ?count) WHERE {

        ?recipe a schema:Recipe ;
                schema:name ?name ;
                schema:recipeInstructions ?instructions ;
                schema:nutrition ?nutrition .
        ?nutrition schema:calories ?calories ;
                   schema:proteinContent ?protein ;
                   schema:fatContent ?fat ;
                   schema:carbohydrateContent ?carbs ;
                   schema:fiberContent ?fiber ;
                   schema:sugarContent ?sugar .
        OPTIONAL { ?recipe schema:recipeCategory ?category . }
        OPTIONAL { ?recipe schema:recipeCuisine ?cuisine . }
        OPTIONAL { ?recipe schema:recipeYield ?servings . }
        ?recipe schema:recipeCategory "Gluten-Free" .

        ?recipe schema:recipeIngredient ?ing_must_0 . FILTER(CONTAINS(LCASE(?ing_must_0), "chicken"))

        FILTER NOT EXISTS { ?recipe schema:recipeIngredient ?ing_avoid . FILTER(CONTAINS(LCASE(?ing_avoid), "nuts")) }




        }

--- End Count Query ---

Found 22 unique recipe(s) matching criteria.
```

1. Spanish Chicken
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 5626 kcal | Protein 70.8g | Fat 82.4g | Carbs 78.6g | Fiber 6.5g | Sugar 0.0g
   Instructions: step 1
Heat oven to 190C/170C fan/gas 5. Put all the ingredients into a large, wide ovenproof dish. Mix everything together with your hands and season.

step 2
Bake for 45 mins, stirring the onion...

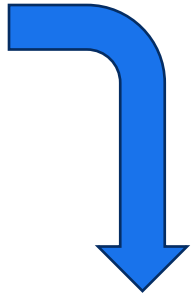
2. Chicken Parmentier
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 4266 kcal | Protein 46.3g | Fat 67.3g | Carbs 81.2g | Fiber 4.6g | Sugar 0.0g
   Instructions: For the topping, boil the potatoes in salted water until tender. Drain and push through a potato ricer, or mash thoroughly. Stir in the butter, cream and egg yolks. Season and set aside.
For the fill...

3. Chicken Basquaise
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 5646 kcal | Protein 39.3g | Fat 88.0g | Carbs 101.7g | Fiber 8.0g | Sugar 0.0g
   Instructions: Preheat the oven to 180°C/Gas mark 4. Have the chicken joints ready to cook. Heat the butter and 3 tbsp olive oil in a flameproof casserole or large frying pan. Brown the chicken pieces in batches on ...

4. Chicken Marengo
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 3053 kcal | Protein 37.3g | Fat 47.0g | Carbs 38.5g | Fiber 3.2g | Sugar 0.0g
   Instructions: Heat the oil in a large flameproof casserole dish and stir-fry the mushrooms until they start to soften. Add the chicken legs and cook briefly on each side to colour them a little.
Pour in the passat...

5. Easy Spanish chicken
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 2758 kcal | Protein 32.3g | Fat 42.4g | Carbs 39.1g | Fiber 3.5g | Sugar 0.0g
   Instructions: step 1
Heat the oven to 200C/180C fan/gas 6. Heat the olive oil in a large ovenproof frying pan over a medium heat and fry the onion, chorizo and peppers along with a pinch of salt and pepper for 15 ...

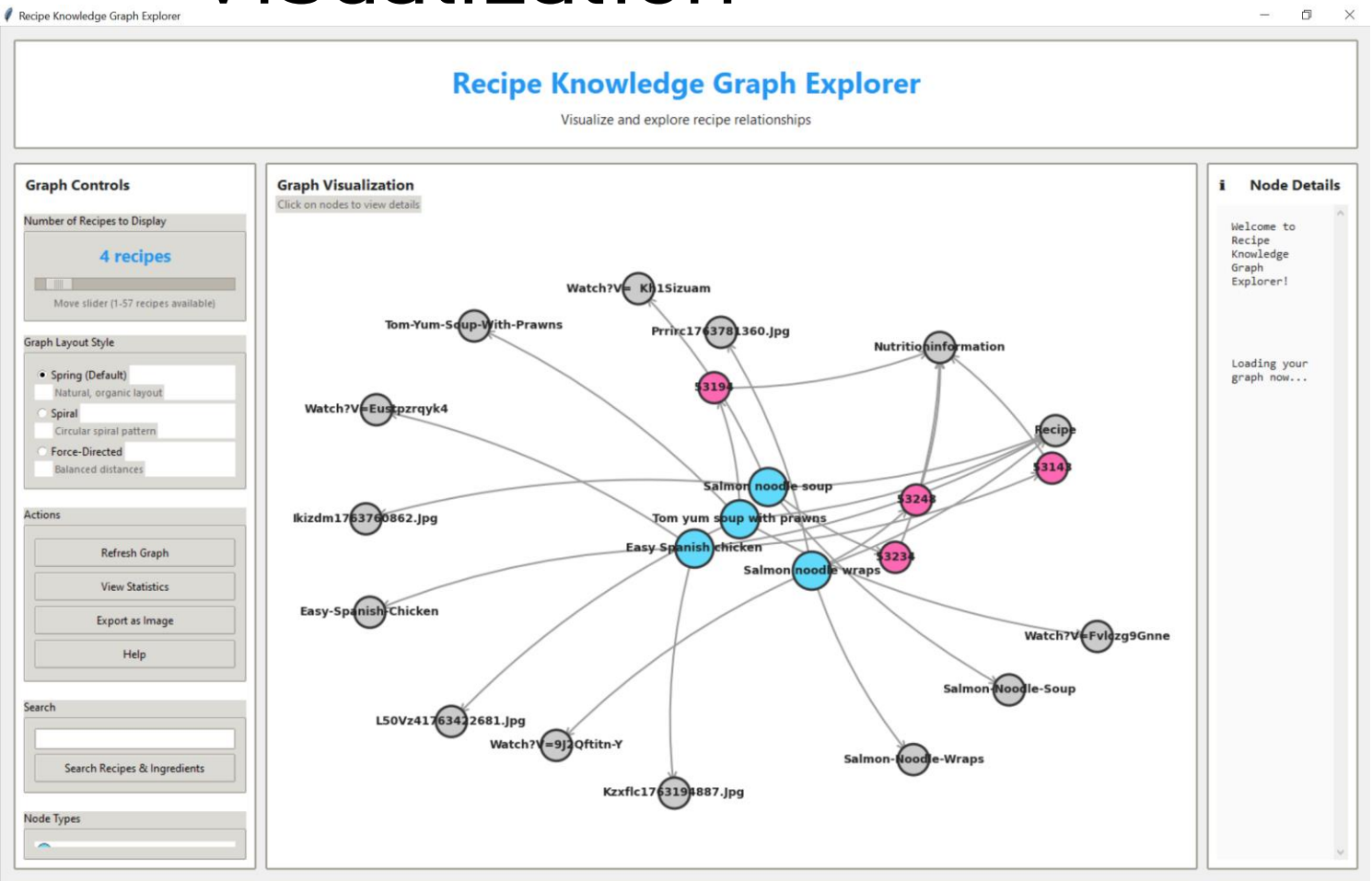
6. Nutty Chicken Curry
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 4539 kcal | Protein 31.8g | Fat 85.3g | Carbs 48.9g | Fiber 3.5g | Sugar 0.0g
   Instructions: Finely slice a quarter of the chilli, then put the rest in a food processor with the ginger, garlic, coriander stalks and one-third of the leaves. Whizz to a rough paste with a splash of water if need...



22. Tom yum soup with prawns
   Servings: 2
   Categories: N/A | Cuisines: N/A
   Nutrition (per serving): 1283 kcal | Protein 4.
   Instructions: step 1
Pour 1.3 litres water into a large saucepan over a ring to a boil, then reduce the...

Suggested substitutions for avoided ingredients:
   Nuts: seeds, oats, coconut

Visualization



Queries

```
#Query 2
#Find ingredients with Tofu

SELECT ?ingredient ?label
WHERE {
    ?ingredient a food:Ingredient ;
    rdfs:label ?label .
    FILTER(CONTAINS(LCASE(?label), "tofu"))
}

#Query 3
#Find ingredients with Peanuts

SELECT ?ingredient ?label
WHERE {
    ?ingredient a food:Ingredient ;
    rdfs:label ?label .
    FILTER(CONTAINS(LCASE(?label),"peanut"))
}
```

- Including & excluding certain ingredients
- Find missing nutritional information & labels
- Classify the different meats

```
#Query 4
#Find ingredients without NutritionInformation

SELECT ?ingredient ?label
WHERE {
    ?ingredient a food:Ingredient ;
    rdfs:label ?label .
    FILTER NOT EXISTS {
        ?ingredient schema:nutrition ?nutrition
    }
}

#Query 5
#Find queries that have missing labels

SELECT ?ingredient
WHERE {
    ?ingredient a food:Ingredient .
    FILTER NOT EXISTS { ?ingredient rdfs:label ?label}
}
```

```
#Query 7
#Which ingredients have more than one NutritionInformation

SELECT ?ingredient (COUNT(?nutrition) AS ?nutritionAmount)
WHERE {
    ?ingredient a food:Ingredient ;
    schema:nutrition ?nutrition .
}
GROUP BY ?ingredient
HAVING (COUNT(?nutrition) > 1)

#Query 8
#Which ingredient is the most common

SELECT ?label (COUNT(?ingredient) AS ?amountOfTimes)
WHERE {
    ?ingredient a food:Ingredient ;
    rdfs:label ?label .
}
GROUP BY ?label
ORDER BY DESC(?amountOfTimes)
```

Graph Unification

- Divided in 3 phases:

- Phase 1: Simple Merge of three sources without modifications
- Phase 2: applied entity linkage between ingredients from all sources
- Phase 3: Normalization script to ensure usage of same vocabulary for all sources

- Pros:

- simple integration with Graph triple store and external API

- faster and more understandable SPARQL queries

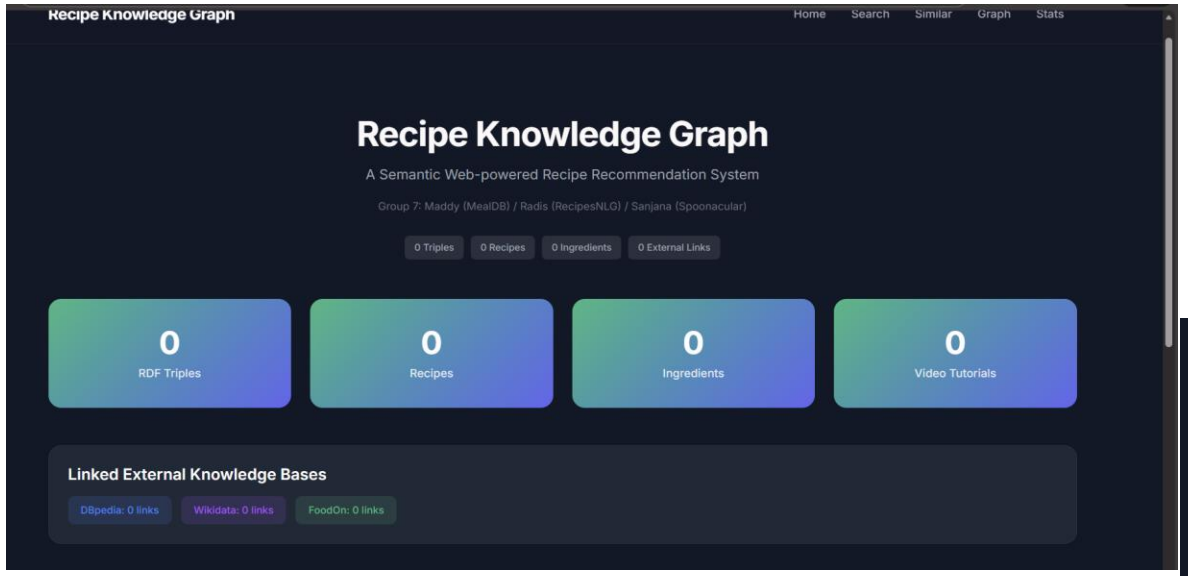
Backend API

- Loaded unified graph into containerized stand alone apache Jena Fuseki instance
- connected a FastAPI instance to Fuseki to execute custom queries

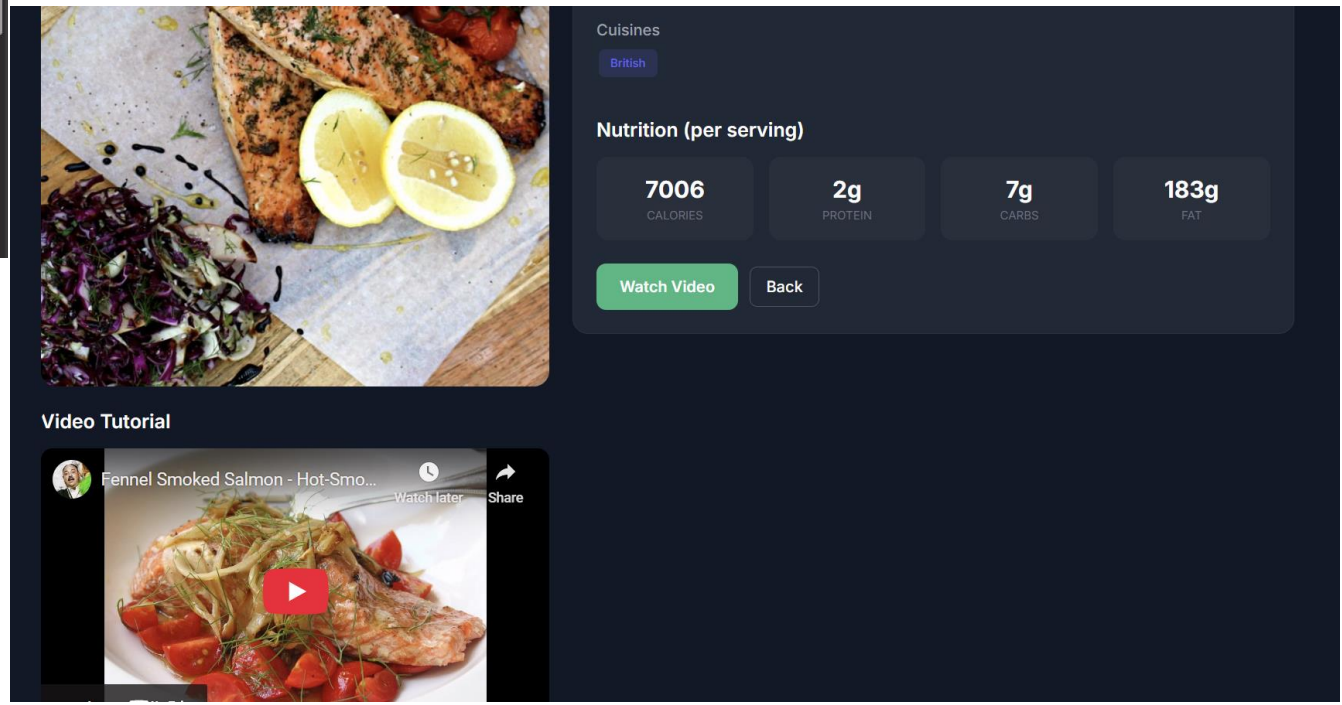
Web Interface

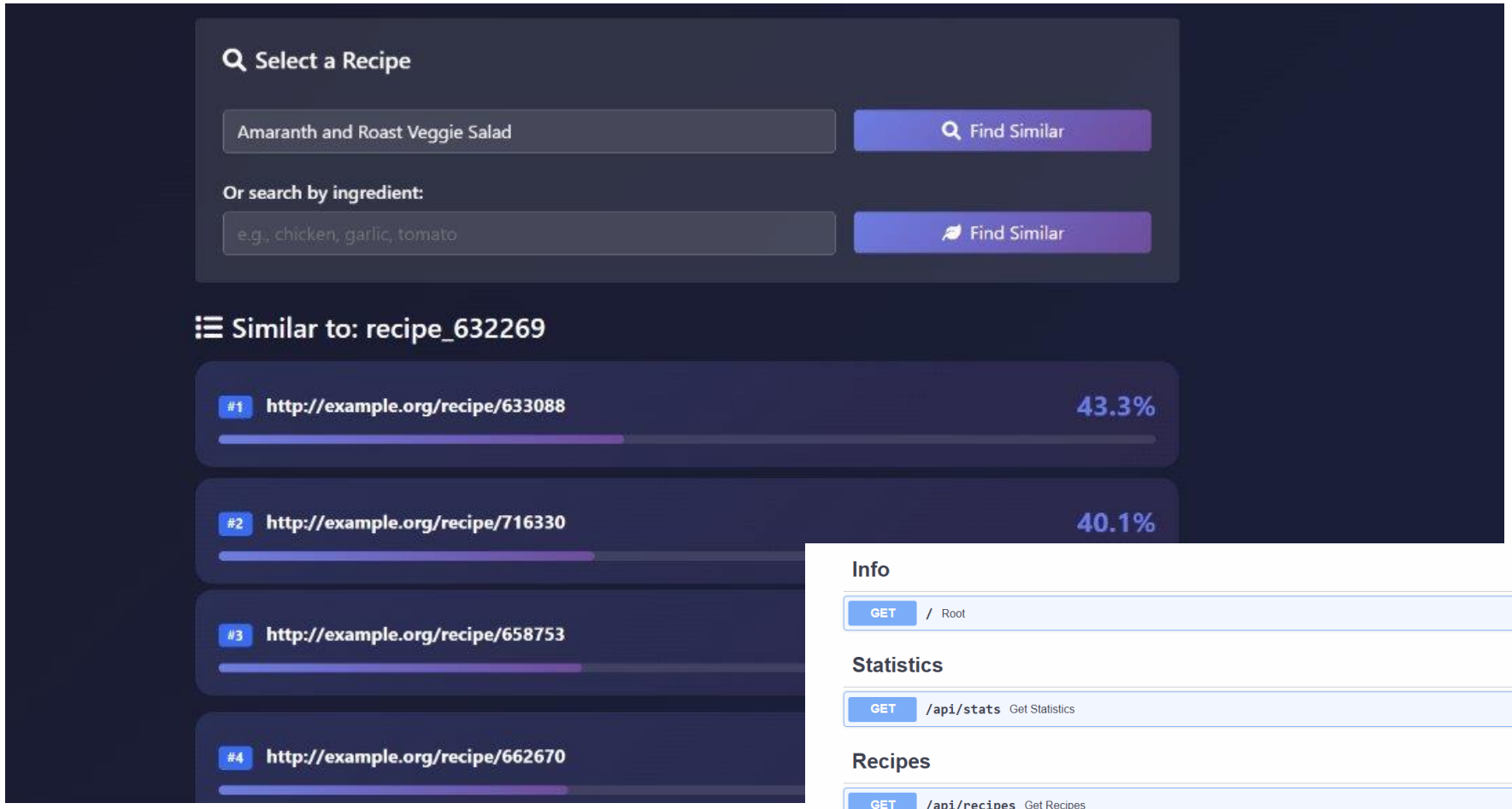
Video Links for Recipes

Links to Original recipe Sources



Dietery Filtering





Info

GET / Root

Statistics

GET /api/stats Get Statistics

Recipes

GET /api/recipes Get Recipes

GET /api/recipes/{recipe_id} Get Recipe

GET /api/search Search Recipes

GET /api/videos Get Recipes With Videos

Ingredients

GET /api/ingredients Get Ingredients

GET /api/ingredients/{ingredient_id} Get Ingredient

Knowledge Graph Embeddings

The Idea

Learn Vector representations for every entity in the Knowledge Graph
Recipes with Similar ingredients, cuisines or diets will have similar vectors.

RotatE Model

Similarity Calculation

cosine_similarity(recipe_A, recipe_B)

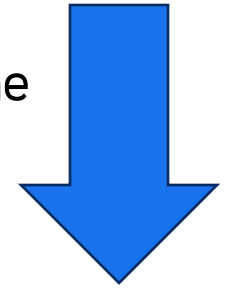
Training Parameters	
Embedding Dimensions	64
Batch Size	256
Epochs	50
Train/Test Split	80/20

Finding Similar Recipes

Mango Fried Rice

Ingredients: Rice, mango, Onion, garlic, soy sauce
Cuisine: Asian
Deit: Vegan, Gluten-free

Calculate Cosine Similarity



Recommended Similar Recipes

Thai Pineapple rice 0.89
Asian | Rice | Pineapple | onion

Vegetable Fried Rice 0.85
Asian | Rice | Vegetables | soy sauce

Asian Stir fry 0.81
Asian | Vegetables| garlic| soy sauce

Coconut Rice 0.76
Asian | Rice | coconut Milk

Limitations & future work

- Same ingredient appears with different names across sources (e.g., "tofu", "firm tofu") making exact matching difficult
- Searching by ingredient returns imprecise results due to inconsistent labeling across sources (e.g., searching "chicken" returns non chicken recipes)
- Different data sources (RecipesNLG, MealDB, Spoonacular) originally used different vocabularies, and while alignment was performed, some inconsistencies are still present

Thank you for your attention!