
A CASE-BASED REASONING SOLUTION FOR PERSONALIZATION OF COOKING RECIPES

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OUTLINE

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PROBLEM DESCRIPTION

- *The Salad Challenge* → *Computer Cooking Contest Workshop* → *International Conference on Case-Based Reasoning 2017*
- **Input:**
 - A list of desired ingredients
 - A list of unwanted ingredients
- **Output:**
 - A salad recipe → respects the two conditions
- **Solution based on:**
 - A base of 68 salad recipes (XML format)
 - An ontology with 2164 culinary ingredients (RDF format)
- **Evaluation:**
 - Scientific quality
 - Culinary quality



MOTIVATION

■ Food waste

- An important issue ➡ $\frac{1}{3}$ of the food produced is wasted annually ➡ high level of raw materials, effort and money losses
- The main reason of food being waste ➡ the neglect of bought food (e.g. out of date, mouldy, inappropriate storage conditions)
- One solution ➡ changing the behaviour of consumers ➡ software for mobile phones / PCs for suggesting various usages of food already owned
- In this thesis ➡ based on a list of available ingredients, a salad recipe is proposed

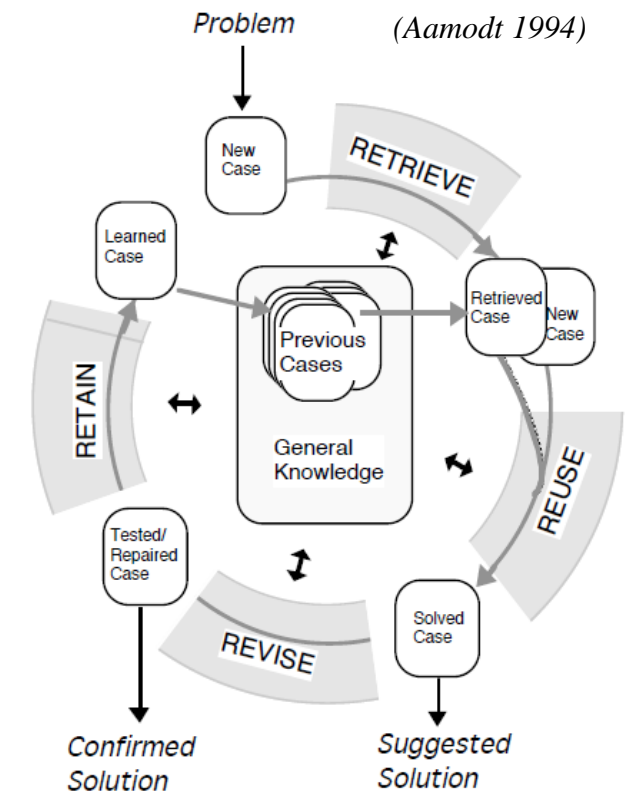
■ Computational creativity

- A subfield of Artificial Intelligence ➡ will have a huge impact in passing the *Turing test*
- Important steps ➡ in domains historically associated with creative people (e.g. poetry, painting, music, culinary)

SOLUTION → OVERVIEW

■ Case-Based Reasoning

- Field of Artificial Intelligence
- Based on:
 - The idea that → similar problems have similar solutions
 - The human reasoning method → reasoning by reusing → solve new problems by reusing similar previously solved problems and adapt them to the current case
- A CBR system → The 4R Cycle
 - **Retrieve** (searching and selecting similar past experiences (cases) in a case-base)
 - **Reuse** (adapting their solutions to fit the current problem)
 - **Revise** (apply the generated solution and evaluate the results)
 - **Retain** (store in memory the new generated problem – solution group)
- Applications in → diagnosis, customer service, recommender systems, medicine, knowledge management, law



SOLUTION → RETRIEVAL

- A case-base → recipes in XML format

```
<recipe>
  <recipeid>14</recipeid>
  <title>Cranberry fruit salad</title>
  <ingredients>
    <ingredient ingredient="walnut" quantity="0.5" unit="c" qualifiers="chopped">1/2 c Chopped walnuts</ingredient>
    <ingredient ingredient="latin" quantity="6" unit="oz" qualifiers="">6 oz Package raspberry gelatin</ingredient>
    <ingredient ingredient="water" quantity="2" unit="c" qualifiers="boiling">2 c Boiling water</ingredient>
    <ingredient ingredient="cranberry_sauce" quantity="16" unit="oz can" qualifiers="">16 oz Can jellied cranberry sauce</ingredient>
    <ingredient ingredient="pineapple" quantity="8.75" unit="oz can" qualifiers="crushed">8 3/4 oz Can crushed pineapple</ingredient>
    <ingredient ingredient="orange_juice" quantity="0.75" unit="c" qualifiers="h">3/4 c Fresh orange juice</ingredient>
    <ingredient ingredient="lemon_juice" quantity="1" unit="tblsp" qualifiers="h">1 tb Fresh lemon juice</ingredient>
  </ingredients>
  <preparation>
    <step>Dissolve gelatin in boiling water</step>
    <step>Break up and stir in cranberry sauce, undrained pineapple, orange juice, lemon juice, and nuts</step>
    <step>Pour into a shallow casserole dish</step>
    <step>Chill until firm</step>
    <step>Cut into squares and serve on lettuce leaves with salad dressing</step>
  </preparation>
  <diet>
    <exclude-for-diet>Nut free</exclude-for-diet>
    <exclude-for-diet>Veganism</exclude-for-diet>
    <exclude-for-diet>Vegetarian</exclude-for-diet>
  </diet>
</recipe>
```

Similarity = a function $sim: E \times E \rightarrow [0, 1]$ → compares two elements from a known domain E → returns a real value usually between 0 (the elements are totally different) and 1 (the elements are identical).

- A query:

- Desired ingredients
- Unwanted ingredients

Find a recipe which fits as well as possible the given query

A perfect match

A similar match

similar problems have similar solutions

SOLUTION → RETRIEVAL

■ Recipe – Query Similarity

- The Recipe has N ingredients
- The Desired list has M ingredients
- Create a N by M table → similarities between ingredients
- Choose M pairs of ingredients (no repetition) → the sum of their similarities to be maximum (*Backtracking*)
- The maximum sum → The Recipe – Query Similarity value

		<i>Desired Ingredients</i>	
		Apple juice	Salmon
<i>Recipe Ingredients</i>	Pineapple	0.7	0.05
	Oil	0.5	0.2
	Shrimp	0.1	0.85

→ 1.55

SOLUTION → RETRIEVAL

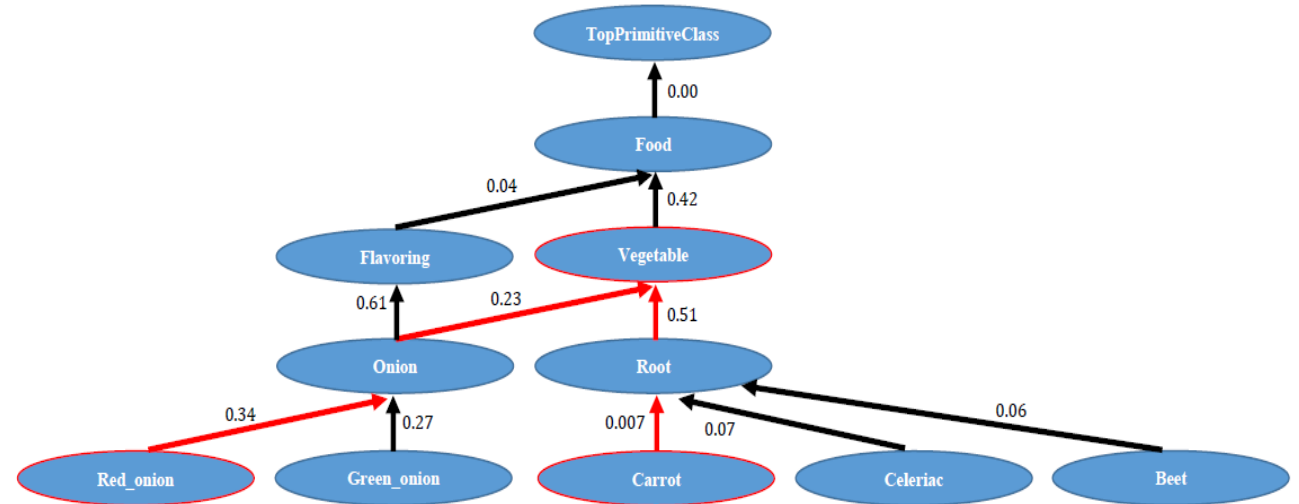
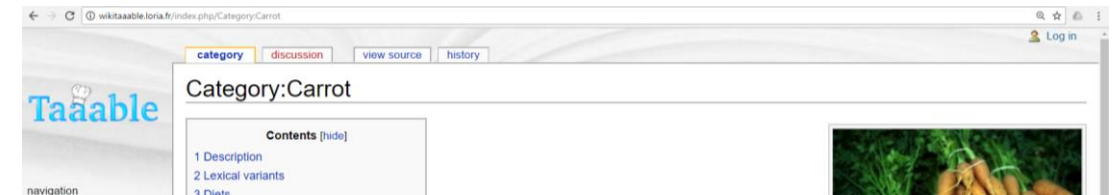
■ Two Ingredients Similarity

- Using the provided food ontology (RDF format)
 - Contains information about each ingredient (wiki pages)

- Energy provided
- Nutritional values
- Diet compatibility
- The parents (e.g. Vegetable - Onion)
- The generalization cost
- Weight conversion

- Can be interpreted → an **Oriented Graph**

- The similarity between two ingredients (two nodes of the graph) → the minimum sum of the paths' costs from the nodes to a common parent node



SOLUTION → REUSAGE

- Adaptation → Only when the retrieval is not perfect !

- **Ingredient Adaptation**

- Ensure the retrieved recipe → fulfills the two conditions
- The unwanted ingredients → avoided through the retrieval stage
- The desired ingredients which are not already in the retrieved recipe have to replace other ingredients →

→ use the previously computed and chosen similarity values between ingredients



- A better binding between ingredients (*lamb* better with *rosemary* than *bay leaves*) → a knowledge base with recommended ingredient combinations (from a human expert or resulted after a learning phase)

	<i>Desired Ingredients</i>	
	Apple juice	Salmon
<i>Recipe Ingredients</i>	Pineapple	0.05
	Oil	0.2
	Shrimp	0.85

Replace *Pineapple* with *Apple juice* and *Shrimp* with *Salmon*

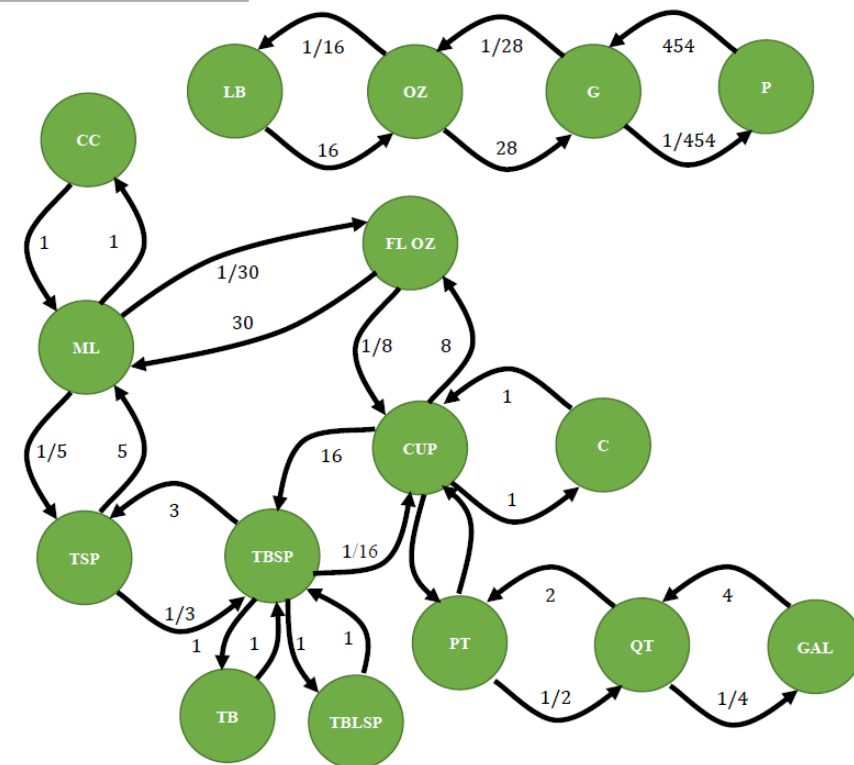
SOLUTION → REUSAGE

■ Ingredient Quantity Adaptation

- Not all the ingredients → use the same measurement unit (e.g. *lemon juice* can be measured in *cups*, whereas *salmon* cannot)
- Not all the ingredients → have the same consistency
- Food ontology → Weight conversion information
- Transform the replaced quantity in *grams* → using the particular weight conversion table **OR** the measurement unit graph
- Transform from *grams* to a specific quantity for the replacement ingredient → choose the biggest value (avoid real values very close to 0)
- Could be taken into account → energy value, nutritional values

Weight conversions

1 c, chopped	128 g
1 c, grated	110 g
1 c, sliced	122 g
1 unit, large	7 g
1 unit, medium	4 g
1 unit, small	50 g
1 unit, slice	3 g



SOLUTION → REUSAGE

■ Preparation Steps Adaptation

- Not always two replaced ingredients → the same usage method
- One solution → replace each occurrence of the replaced ingredient with the name of the replacement ingredient
- This approach → not always leads to very good results
 - wrong obtained steps from the cooking point of view (e.g. *shrimp* is replaced with *lemon juice*, then the preparation 'Bring the water to boil; add the lemon juice and cook 3 to 5 minutes' it makes no sense)
 - the preparation steps may contain the plural or a shorter version of the ingredient name (e.g. *mayonnaise* instead of *light mayonnaise*) → does not lead to a replacement
- The most difficult adaptation among all → adaptation has to be done at semantic level
- A knowledge base → adequate preparation steps for each ingredient (from a human expert or from a learning phase)



SOLUTION → REVISION

- When the retrieved recipe has to be adapted → has to be evaluated by a human expert → verify the correctness and the quality
- The human expert → can improve it or can give a rating (which can be used for retrieval)



SOLUTION → RETAINING

- If the human expert considers the new recipe to be a valuable one → store it in the recipe case-base
- Before storage → convert the recipe to XML format → because the case-base is an XML file

RESULTS

- The results obtained ➡ to be analysed from the qualitative point of view, one by one

- **Query 1: Perfect match**

- *Desired ingredients:* onion, shrimp, pea

- *Unwanted ingredients:* oil, bacon

- A perfect recipe match is found:

Macaroni-shrimp salad

- No adaptations have to be performed
 - No update of the case-base has to be done

```
<recipe>
  <recipeid>36</recipeid>
  <title>Macaroni-shrimp salad</title>
  <ingredients>
    <ingredient ingredient="salt" quantity="0.5" unit="sp" qualifiers="">1/2 ts Salt</ingredient>
    <ingredient ingredient="pepper" quantity="0.13" unit="sp" qualifiers="">1/8 ts Pepper</ingredient>
    <ingredient ingredient="" quantity="2" unit="" qualifiers="hard-boiled,chopped">2 Hard-cooked eggs, chopped</ingredient>
    <ingredient ingredient="lettuce" quantity="" unit="" qualifiers="">Lettuce leaves</ingredient>
    <ingredient ingredient="water" quantity="4.5" unit="c" qualifiers="">4 1/2 c Water</ingredient>
    <ingredient ingredient="shrimp" quantity="1" unit="lb" qualifiers="npeeled,medium,fresh">1 lb Shrimp, unpeeled medium, fresh</ingredient>
    <ingredient ingredient="elbow macaroni" quantity="1.5" unit="c" qualifiers="cooked">1 1/2 c Cooked elbow macaroni</ingredient>
    <ingredient ingredient="pea" quantity="1" unit="c" qualifiers="ozen,thawed">1 c Frozen peas, thawed</ingredient>
    <ingredient ingredient="sweet_pepper" quantity="1" unit="" qualifiers="medium,chopped">1 md Bell pepper, chopped</ingredient>
    <ingredient ingredient="pimiento" quantity="0.5" unit="c" qualifiers="chopped">1/2 c Chopped pimiento</ingredient>
    <ingredient ingredient="onion" quantity="1" unit="tblsp" qualifiers="chopped">1 tb Chopped onion</ingredient>
    <ingredient ingredient="sour_cream" quantity="0.25" unit="c" qualifiers="">1/4 c Lite sour cream</ingredient>
    <ingredient ingredient="mayonnaise" quantity="0.5" unit="c" qualifiers="">1/2 c Lite mayonnaise</ingredient>
  </ingredients>
  <preparation>
    <step>Bring the water to a boil; add the shrimp and cook 3 to 5 minutes</step>
    <step>Drain well and rinse with cold water</step>
    <step>Chill</step>
    <step>Peel and devein shrimp</step>
    <step>In a large bowl, combine the shrimp and all ingredients except the mayonnaise, salt, and pepper</step>
    <step>Toss well</step>
    <step>Whisk together the mayonnaise, salt, and pepper and pour over shrimp mixture, tossing gently</step>
    <step>Chill</step>
    <step>Spoon the salad onto lettuce leaves and sprinkle with paprika to serve</step>
    <step>Add thin slices of avocado or wedges of tomato for a colorful touch</step>
    <step>Do you have a basket of decorated Easter eggs sitting on your kitchen counter? Why not put these hard-boiled beauties to good use in one of this week's healthy recipes</step>
  </preparation>
  <diet>
    <exclude-for-diet>Cholesterol diet</exclude-for-diet>
    <exclude-for-diet>Gluten-free diet</exclude-for-diet>
    <exclude-for-diet>Veganism</exclude-for-diet>
    <exclude-for-diet>Vegetarian</exclude-for-diet>
  </diet>
</recipe>
```

RESULTS

■ Query 2: Not a perfect match but good adaptations

- *Desired ingredients:* pineapple, onion

- *Unwanted ingredients:* sugar, oil

- A perfect recipe cannot be found

- The most similar recipe:

Lighter chicken waldorf salad

- Change mango with pineapple and celery with onion ➡ feasible changes

- Change quantities:

- 1 mango unit = 207 grams = 3.7 pineapple units

- 1 celery unit = 110 grams = 18.3 onion units

- Change one preparation step: 'Combine with the apple, celery, mango and candied ginger' ➡ 'Combine with the apple, onion, pineapple and candied ginger'

- The case-base can be updated if the users wants

```
<recipe>
<recipeid>173</recipeid>
<title>Lighter chicken waldorf salad Adapted</title>
<ingredients>
  <ingredient ingredient="chicken_breast" qualifiers="oasted" quantity="0.75" unit="lb">0.75 lb oasted chicken_breast</ingredient>
  <ingredient ingredient="anny_smith_apple" qualifiers="medium,cored" quantity="1.0" unit="">1.0 medium,cored anny_smith_apple</ingredient>
  <ingredient ingredient="onion" qualifiers="" quantity="18.3" unit="units">18.3 units onion</ingredient>
  <ingredient ingredient="pineapple" qualifiers="" quantity="3.7" unit="unit">3.7 unit pineapple</ingredient>
  <ingredient ingredient="crystallized_ginger" qualifiers="minced" quantity="2.0" unit="blsp">2.0 blsp minced crystallized_ginger</ingredient>
  <ingredient ingredient="light_mayonnaise" qualifiers="" quantity="0.33" unit="c">0.33 c light_mayonnaise</ingredient>
  <ingredient ingredient="fat-free_sour_cream" qualifiers="" quantity="0.33" unit="c">0.33 c fat-free_sour_cream</ingredient>
  <ingredient ingredient="lime_juice" qualifiers="" quantity="2.0" unit="blsp">2.0 blsp lime_juice</ingredient>
  <ingredient ingredient="mango_chutney" qualifiers="" quantity="2.0" unit="blsp">2.0 blsp mango_chutney</ingredient>
  <ingredient ingredient="ainy_mustard" qualifiers="" quantity="1.0" unit="sp">1.0 sp ainy_mustard</ingredient>
  <ingredient ingredient="walnut" qualifiers="coarsely chopped" quantity="3.0" unit="blsp">3.0 blsp coarsely chopped walnut</ingredient>
  <ingredient ingredient="mint" qualifiers="minced,fresh" quantity="2.0" unit="blsp">2.0 blsp minced,fresh mint</ingredient>
</ingredients>
<preparation>
  <step>1</step>
  <step>Dice the cooked chicken</step>
  <step>Combine with the apple, onion, pineapple and candied ginger</step>
  <step>In a medium bowl, combine the mayonnaise, sour cream, lime juice, chutney and mustard; mix well</step>
  <step>Add to the salad, mixing well</step>
  <step>Cover and refrigerate until ready to serve</step>
  <step>Just before serving, stir in the chopped walnuts and mint</step>
  <step>Note: Waldorf salad is typically chock full o' fat; this one has some fat, but less fat than the traditional recipe</step>
  <step>Candied or sugared ginger can be found in the Asian section of major supermarkets</step>
</preparation>
<diet>
  <exclude-for-diet>Cholesterol diet</exclude-for-diet>
  <exclude-for-diet>Nut free</exclude-for-diet>
  <exclude-for-diet>Veganism</exclude-for-diet>
  <exclude-for-diet>Vegetarian</exclude-for-diet>
</diet>
</recipe>
```

RESULTS

■ Query 3: Not a perfect match and insufficient adaptations

- *Desired ingredients:* salmon, lemon juice, onion
- *Unwanted ingredients:* oil, vanilla
- A perfect recipe cannot be found
- The most similar recipe: Crab and pea salad elegante
- Change crab meat with salmon and lettuce with onion ➡ feasible changes
- In this recipe ➡ onion is already present ➡ name is _onion ➡ not recognizable by the program
- The lettuce has no quantity specified ➡ the resulted quantity for onion is 0
- In the preparation step '*Combine mayonnaise, mustard, lemon juice, and curry powder; stir well and add to crab mixture*'
➡ the term crab appears and not crab meat ➡ no replacement
- In the preparation step '*Serve on lettuce leaves*' ➡ if lettuce is replaced with onion ➡ meaningless result

CONCLUSIONS

- A solution for ➡ *The Salad Challenge* task within *Computer Cooking Contest* workshop held during the *International Conference on Case-Based Reasoning 2017* was presented
- The solution is based on Artificial Intelligence's field ➡ Case-Based Reasoning ➡ similar problems have similar solutions
- The purpose of this application:
 - Contribution to reduction of food waste
 - Contribution to development of Computational Creativity
- The results obtained are good ➡ behavior in some corner cases can be improved

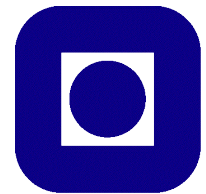
CONCLUSIONS

■ Improvements:

- Verification by a human expert ➡ ingredients name, quantities and units
- Creation of a base of similar names for ingredients (e.g. crab meat - crab)
- Creation by a human expert (or using a learning phase) of specific usages of ingredients
- The quantity adaptation ➡ using also the energy value and the nutritional values of the ingredients involved in the replacement
- Creation of a knowledge base of binding ingredients ➡ obtain a better taste of the final salad
- Adapt all the ingredient quantities ➡ to obtain only integer values, or half or quarters of integer values
➡ easiness in cooking.

REMARKS

*'Machine Learning and
Case-Based Reasoning'* course
Spring Semester 2017



NTNU
Norwegian University of
Science and Technology

Improve the Solution



participate at

