

# Solving the Cocktail Challenge with a Case Based Reasoning System

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## Introduction

We developed a Case Based Reasoning (CBR) system fine tuned for the [Cocktail Challenge](#) (CC) from the Computer Cooking Contest. We put our focus on implementing an adaption function that suits the given application domain. The small number of cases in the challenge allows the use of a flat structure for the Case Library. A more general idea that can be derived from our project is how we compute the similarity measure: The adaption function is simulated for each case in the case library. We log the number of adaptations that had to be made for each candidate case to match the user's query. The case that requires the smallest number of adaptations is chosen. Our case structure follows the vanilla approach given on [lecture slide 13](#).

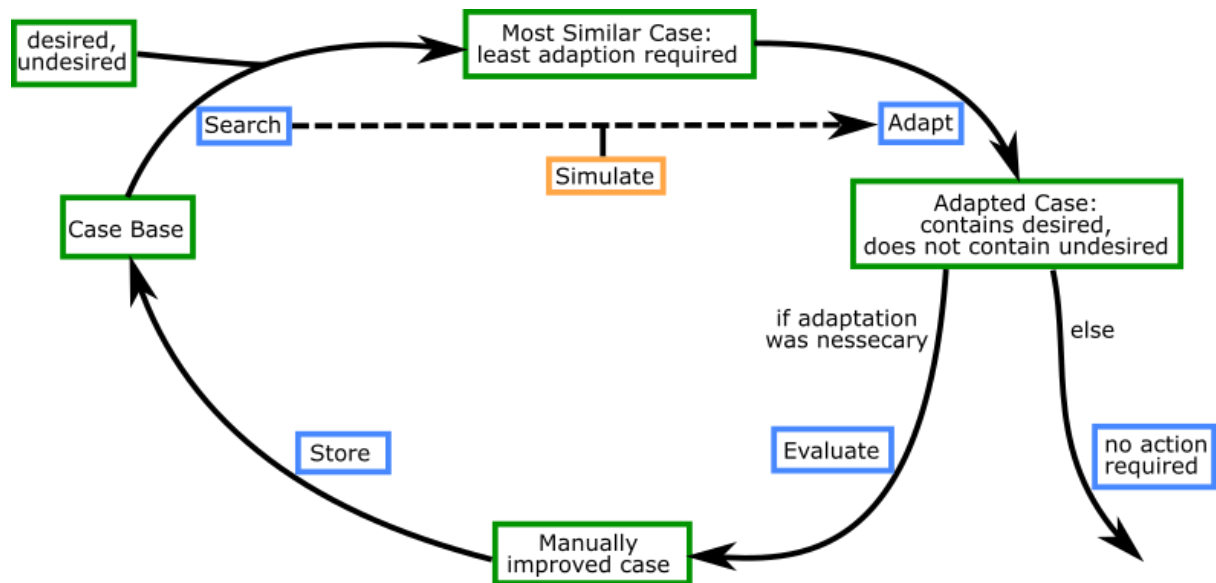
## Requirements

The requirements of the system are defined by the CC. In the CC the user provides a set of desired ingredients and a set of undesired ingredients (the query). The objective is to return a cocktail that contains all desired ingredients and no undesired ones. The returned cocktail should have a good taste. It should be noted that no quantities are provided by the user. This allows the system to choose arbitrary quantities to achieve the objective of good taste. However, the approach can be easily abstracted. Whenever the applications domain allows a case to be meaningfully described by a set of identifiers and each identifier (here: ingredient) can be annotated by a numerical value (here: quantity) our proposed solution might be used, given that the user does not want to directly specify the numerical values. Further it makes sense to judge generated solutions (here: cocktails) by an expert. Therefore the system should include an option to evaluate generated solutions and in case of a bad solution it should offer a possibility for manual improvement.

Our CBR project only requires little computational power and memory capacity. The system responds instantaneously on average consumer hardware for a small case bases like the CC, even when adding a magnitude (in comparison to the official cases provided by the challenge description) of cases to the case base.

## Functional Architecture

The blue boxes are the components of the CBR engine while the green boxes are the inputs or outputs of those components. The architecture mostly follows the scheme of Aamodt & Plaza, but uses a simulation of the “Adapt” component for the similarity search.



## Implementation details

A query is processed by doing a full search in the flat case base. Hierarchical case bases offer faster query times while potentially degrading the quality of the returned results. Since we noticed that for the case base of the CC the performance with a simple flat structure is sufficient (instantaneous response on consumer hardware) we decided to keep using the flat structure. There exists no function of its own that computes the similarity between the query and a given case. Rather we execute the adaption routine for every case in the case base. The adaption routine makes sure that the case contains every desired identifier and no undesired ones. The resulting adapted case is discarded, but we keep track of the number of necessary modification steps. We then merely define the case that needed the lowest number of modification steps as the most similar one to the query. The number of modification steps define a distance function with the desired property that a case that contains all desired identifiers and no undesired ones will have zero distance to the query.

Before explaining the details of the CC specific adaptation routine, we want to remark that we annotated the case base with ingredient categories. As can be seen in `Data/categories.xml` we divided the ingredients into the four categories nonalcoholic, alcoholic, special and fruit. For that matter we automatically extracted all ingredients from the case base and then manually added category information.

After having obtained a good candidate case we perform once again the actual adaption routine on it. Note that this will just yield the same result as the one obtained during the first step. Yet we decided on not caching the candidates to reduce memory usage. The adaptation of one case takes an inconsiderable amount of processing time. From here on we will use the following terminology for ingredients:

missing desired ingredient	Ingredients that are desired, but are not in the candidate cocktail
contained undesired ingredient	Ingredients that are in the candidate cocktail, but are undesired
optional ingredients	Ingredients that are in the cocktail, but a neither desired nor undesired

The goal of the adaptation is that the both the sets of missing desired ingredients and contained undesired ingredients are empty. We try to make as little change as possible to the original cocktail, since we assume that the original cocktails taste well, as they were created by human experts. For that we developed four different strategies. We explain the strategies in the order of their favorableness.

The most favorable strategy is to replace a contained undesired ingredient by a missing desired ingredient. With only one replacement we reduce the size of both sets by one. However, we only perform the replacement when the missing desired ingredient and the contained undesired ingredient are in the same ingredient category (as specified by our manual annotation). This is motivated by the assumption that the general composition of a cocktail should be altered as little as possible.

After this strategy was applied as often as possible and the missing desired ingredient and contained undesired ingredient sets are still not empty we employ the next strategy. Try to replace optional ingredients by missing desired ingredients given that their categories match. To get rid of the remaining contained undesired ingredients, they are replaced by random ingredients from the same category. The order of the second and third strategy does not matter since the operations are commutable.

If the first and second strategy could not add all missing desired ingredients, since there were no contained undesired ingredients or optional ingredients of the same category in the candidate cocktail we added a fall back strategy of adding a small amount of the remaining ingredients to the cocktail. Since this operation changes the composition of the cocktail it is the most unfavorable one.

We penalize the last strategy by counting it as two modification steps. Therein also lies one of the advantages of our “search-by-simulate”-approach. We are able to manually specify the kind of cases that we deem fitting in a dynamic way. Note that this defines a rich and complex distance function that also incorporates the information defined in our categories. For other application domains the distance function defined by that approach might be even more complex, considering that we are using a fairly simple one for the CC.

If any adaptations had to be made to the candidate cocktail, i. e. we started with a non empty missing desired ingredients set or a non empty contained undesired ingredients set, we give the user the possibility to judge the adapted cocktail. An expert user that is not pleased with the recommendation by the CBR system has the possibility to alter the recipe manually. As a last step the adapted cocktail is added to the case base.

## Evaluation

The evaluation of the CBR system based on the CC is problematic, since the objective of good taste is subjective. A formal way to assess the quality of the cocktails would be to ask experts to rate the generated recipes in a user study. Here we merely discuss informally some results based on common sense reasoning and our personal opinion about what makes a good cocktail. Let us begin with a positive result:

```
Searching for a cocktail with constraints
  desired ingredients: {'apple juice', 'white rum'}
  undesired ingredients: set()
```

Most similar cocktail found:

```
Piña Colada (cocktail)
125g malibu rum
150g light whipping cream
20cl pineapple juice
20cl white rum
0 ice cube
```

These desired ingredients are missing: {'apple juice'}

Adapting cocktail so that it contains all desired ingredients and no undesired ones.

Since the missing desired ingredient apple juice and the optional ingredient pineapple juice are of the same category we can replace pineapple juice by apple juice

Current cocktail:

```
Piña Colada (cocktail) with apple juice instead of pineapple juice
125g malibu rum
150g light whipping cream
20cl apple juice
20cl white rum
0 ice cube
```

The found cocktail is well suited for adaptation since it contains one desired ingredient (white rum) and has an optional ingredient (pineapple juice) that can be replaced by our other desired ingredient (apple juice). Note that at this point no cocktail exists in the case base that both contains white rum and apple juice. In our opinion here you can see that it is beneficial to choose an ingredient of the same category for replacement. Imagine we would have

replaced the whipping cream by the apple juice. This would still lead to a solution that contains all desired ingredients and no undesired ones, but would modify the composition of the original cocktail “Piña Colada” in a more severe way. The next example shows a more complex query:

Searching for a cocktail with constraints

```
desired ingredients: {'brown sugar', 'anise basil', 'gin',  
'champagne', 'sparkling water', 'lemongrass', 'ice cube'}  
undesired ingredients: {'lime', 'white rum'}
```

Most similar cocktail found:

Mojito with Basil

5cl white rum

10cl sparkling water

5cl cane sugar syrup

1tsp brown sugar

1 lime

0 anise basil

0 ice cube

These desired ingredients are missing: {'lemongrass', 'gin',  
'champagne'}

These undesired ingredients are contained: {'lime', 'white rum'}

Adapting cocktail so that it contains all desired ingredients and no undesired ones.

Since the missing desired ingredient gin and the contained undesired ingredient white rum are of the same category alcoholic we can replace white rum by gin

Current cocktail:

Mojito with Basil with gin instead of white rum

5cl gin

10cl sparkling water

5cl cane sugar syrup

1tsp brown sugar

1 lime

0 anise basil

0 ice cube

These desired ingredients are missing: {'lemongrass', 'champagne'}

These undesired ingredients are contained: {'lime'}

Since the missing desired ingredient lemongrass and the optional ingredient cane sugar syrup are of the same category we can replace cane sugar syrup by lemongrass

Current cocktail:

Mojito with Basil with gin instead of white rum with lemongrass instead of cane sugar syrup

5cl gin

10cl sparkling water

5cl lemongrass

1tsp brown sugar

1 lime

0 anise basil

0 ice cube

These desired ingredients are missing: {'champagne'}

These undesired ingredients are contained: {'lime'}

We replace the contained undesired ingredient lime by the random ingredient grapefruit of the same category fruit

Current cocktail:

Mojito with Basil with gin instead of white rum with lemongrass instead of cane sugar syrup with grapefruit instead of lime

5cl gin

10cl sparkling water

5cl lemongrass

1tsp brown sugar

1 grapefruit

0 anise basil

0 ice cube

These desired ingredients are missing: {'champagne'}

We add a little bit of the missing desired ingredient champagne

Current cocktail:

Mojito with Basil with gin instead of white rum with lemongrass instead of cane sugar syrup with grapefruit instead of lime and a bit of champagne

5cl gin

10cl sparkling water

5cl lemongrass

1tsp brown sugar

1 grapefruit

0 anise basil

0 ice cube

1cl champagne

The found result contains four of the seven desired ingredients, but also the two undesired ones. This is not that severe because the undesired ingredient white rum can be replaced right away by the desired ingredient gin. Here we can again see how important the

categories are for making sensible replacements. We chose this example because it showcases the application of all four of our rules including the last one.

We remove the remaining undesired ingredient lime by the randomly chosen replacement ingredient grapefruit. Since grapefruit and lime are from the same category fruit, again the composition of the original cocktail is not too heavily changed.

It gets evident that the application of the last strategy, which is more of a fall back strategy to forcefully add the remaining desired ingredients, leads to a somewhat heuristic result. This could be improved in future work.