Learning in Case-Based Reasoning

- Records of problem-solving and interpretation are stored in memory
- Cases contain *ungeneralized* experiences and lessons
- New reasoning remembers and adapts prior cases

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Case-based planning

CHEF (Hammond, 89) builds new recipes from cases representing previous recipes. A Sample task:

A sample task:

- Input goals:
  - make a stir-fry dish
  - include beef
  - include broccoli

Two real-world applications: bioprocess planning and military force deployment

2

Similarity and retrieval

- CHEF bases similarity judgments on a hierarchy of important features
- Dish type is most important, then meat type, then vegetable types, …
- Example: Given the goal of beef and broccoli, CHEF retrieves recipe for beef and green beans.

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Adapting a case to fit

CHEF uses two types of adaptation knowledge:

- *modification rules* for structural changes (e.g., additions and reorderings)
- *ingredient critics* to adjust for individual items

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A *modification rule* for adding fruit to a souffle

```
(add:mod
  index (fruit style-souffle)
  amount (cup number (1))
  steps ((do (chop object ?new-item size (pulp)))
         (before (pour object ?object
                      into (nine-inch-baking-dish))
           do (mix object ?new-item with ?object))))
```

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An *ingredient critic* for shrimp

```
(add:crit shrimp
   binds (shrimp *new-item*)
   steps ((before (cook-step object *new-item*)
            do (shell object *new-item*))))
```

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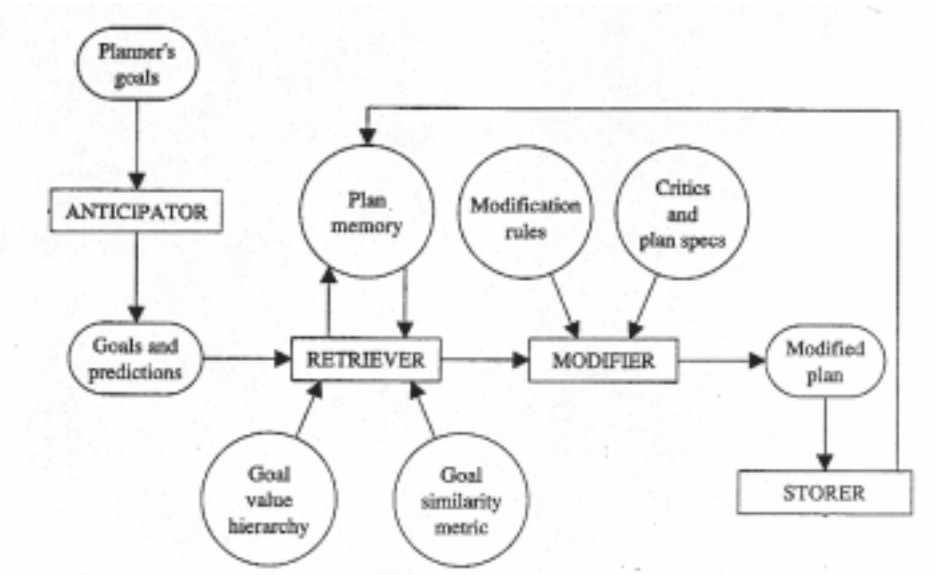
Summary of CHEF's Architecture



How CHEF Generates a Plan for Beef and Broccoli

- Retrieve beef and green beans
- Apply modification rule to substitute broccoli for green beens
- Apply ingredient critic to add chopping step and adjust cooking time

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Voilà! Beef with broccoli

- Ingredients: 1/2 pound beef, 1 tsp sugar, 2 Tbs soy sauce, 1/2 lb. Broccoli, 1 tsp rice wine,1 tsp salt, 1/2 tsp corn starch,1 clove garlic
- Chop the garlic into pieces the size of matchheads.
- Shred the beef.
- Marinate the beef in the garlic, sugar, corn starch, rice wine and soy sauce.
- Chop the broccoli into chunks.
- Stir fry the spices, rice wine and beef for one minute.
- Add the broccoli to the spices, rice wine and beef.
- Stir fry the spices, rice wine, broccoli and beef for three minutes.
- Add the salt.

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Evaluating result

- Check result against adapted recipe goals:
  - The beef is tender.
  - The dish tastes savory.
  - The broccoli is crisp.
  - The dish is salty.
  - The dish is sweet.
  - The dish tastes like garlic.

- Plan is executed (in simulator) and checked against expectations.

But the broccoli is soggy!

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CHEF's recovery from failure

- Explain: Beef releases water => broccoli steams.
- Identify problem pattern:
  - Water released by cooking the beef disabled ``dry wok.''
  - SIDE-EFFECT:DISABLED-CONDITION:CONCURRENT
- Retrieve repair strategies for the problem pattern:
  - Split-and-reform.
  - Alter-plan:side-effect
  - Adjunct-plan
- Split-and-reform applies.
- New plan works!

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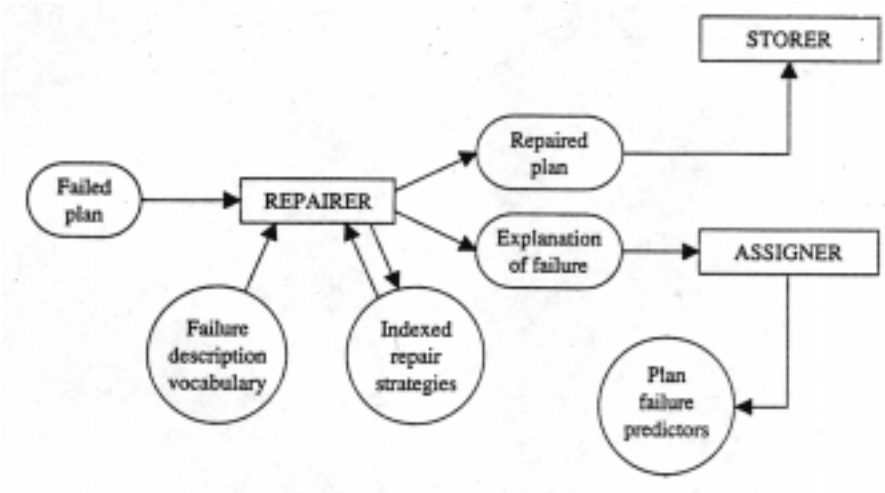
Failure Recovery Architecture



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Learning from experience

- CHEF stores plans under the combinations of goals they satisfy, including the problems they avoid.
- It learns:
  - A new case: the recipe for beef and broccoli, indexed under
    - Goals (stir-fry, beef, broccoli)
    - Problem avoided (avoids bad meat/vegetable interaction)
  - A rule for anticipating meat/crisp vegetable interaction problems

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CBR as Learning

- Learning from success
  - Save successful solutions
- Learning from failures
  - Learn to anticipate and avoid problems
- Purposes of learning
  - Improving competence
  - Speedup

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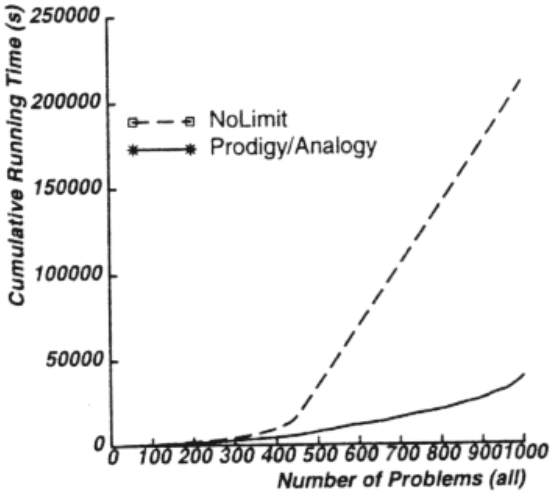
Prodigy Evaluation (Veloso, 94)



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The Hard Problems

- Indexing
- Situation assessment
- Capturing adaptation knowledge
- Keeping cases and indices up-to-date

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Most Active Research Areas in CBR

- Case adaptation
- Case-base maintenance
- Interactive CBR

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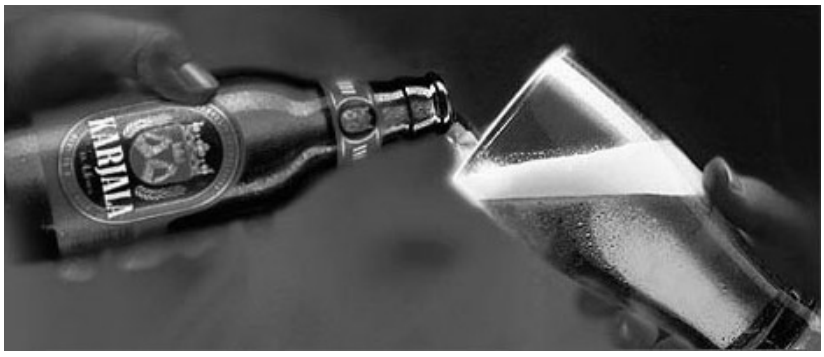
Better Living Through Machine Learning



VTT Biotechnology in Helsinki has applied CBR to beer production and fielded their system in Finnish breweries.

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