

Robot Chef Task Report

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Abstract

This report describes the development and implementation of the Robot Chef task. The objective of this project is to...

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1 Introduction

This assignment involves designing a plan for a robot chef operating within the structured environment of a Japanese restaurant kitchen in Barcelona to autonomously handle meal

preparation tasks. The robot’s objective is to receive digital orders, gather required ingredients, perform necessary preparation and cooking steps, and plate finished dishes for serving. Operating within a divided kitchen layout, the robot must navigate across specific areas for storage, preparation, cooking, serving, and dishwashing, while adhering to operational constraints such as limited carrying capacity and the need for tool sanitation after each use.

The planning solution is implemented using the Planning Domain Definition Language (PDDL), which defines the necessary actions, predicates, and conditions to enable the robot to effectively fulfill its tasks. This report provides a comprehensive analysis of the problem, including the structure of the PDDL model, testing cases across different scenarios, and results demonstrating the robot’s adaptability to diverse dish requirements, resource management, and task optimization. The following sections detail the problem setup, solution framework, and evaluation of scenario-based testing to assess the robot’s performance, efficiency, and flexibility.

2 Methodology and implementation details

We now define the predicates and actions that we are using in the PDDL implementation. The predicates define the state of the world (in this case, the kitchen and its elements), such as valid rooms and their adjacencies, the location of tools, and the condition of ingredients. Actions describe the possible operations the robot can perform, including moving around the kitchen, picking up items (tools, ingredients and dishes), and using them to assemble the required dishes.

2.1 Predicates

- `(at ?x - portable ? - room)`: A *portable* object is located in a specific room.
- `(clean ?tool - tool)`: The *tool* is clean.
- `(holding ?x - item)`: The robot is holding the *item*.
- `(not-holding)`: The robot is not holding anything.

2.2 Actions

- **move**: Robot transitions from one room to another. It requires three parameters: the robot itself, the room it is moving from, and the room it is moving to. The precondition for this action is that the robot must currently be in the room it is moving from, and the destination room must be adjacent to the current room. Upon successful execution of the action, the robot will be located in the new room, and it will no longer be in the original room.
- **pick-up**: The robot picks up an item in the same room. The action is defined with the following parameters: a robot, an item, and a room. The precondition for this action is that both the robot and the item must be in the same room, and the robot must not be holding anything.

- **pick-up-ingredient:** The robot retrieves an ingredient from storage. Parameters include a robot, an ingredient, a dish, and a room. Preconditions require the robot and ingredient to be in the storage room, the ingredient to be stored, the robot not holding anything, and the ingredient to be part of the dish. The effect is that the robot holds the ingredient, the ingredient becomes available, and it is no longer stored.
- **drop-tool:** The robot drops a tool in a designated room. Parameters include a robot, a tool, and a room. Preconditions require the robot to be in the room, holding the tool, and the tool to be used in that room. The effect is that the robot is no longer holding the tool, and the tool is located in the room.
- **drop-ingredient-at-prep:** The robot drops an ingredient in a preparation room. Parameters include a robot, an ingredient, and a room. Preconditions require the robot to be in the room, holding the ingredient, and the room to be either designated for ingredient preparation or a general preparation room. The effect is that the robot is no longer holding the ingredient, the robot is not holding anything, and the ingredient is located in the room.
- **prepare-ingredient:** The robot prepares an ingredient using a tool in a designated room. Parameters include a robot, an ingredient, a tool, and a room. Preconditions require the robot and ingredient to be in the preparation room, the robot to hold the tool, the tool to be used in that room, and the tool to be clean. The effect is that the ingredient becomes prepared, and the tool is no longer clean.
- **cook-ingredient:** The robot cooks a prepared ingredient in the cooking room. Parameters include a robot, an ingredient, and a room. Preconditions require the room to be designated for cooking, the robot to be in the cooking room, the ingredient to be prepared, and the robot to be holding the ingredient. The effect is that the ingredient becomes cooked.
- **assemble-dish:** The robot assembles a dish in the preparation room. Parameters include a robot, a dish, and a room. Preconditions require the robot to be in the preparation room. The `forall` function is used to ensure that for every ingredient in the dish, if the dish requires the ingredient to be prepared, then the ingredient must be prepared and located in the room. Similarly, if the dish requires the ingredient to be cooked, then the ingredient must be cooked and located in the room. The effect is that the dish becomes prepared and is located in the room. The `forall` function is also used in the effect to ensure that for every ingredient in the dish, the ingredient is no longer available, prepared or cooked, as well as not located in the room.

The *forall* function in PDDL is used to specify conditions that must hold for all objects of a certain type. In the context of the **assemble-dish** action, it ensures that the preconditions and effects apply to all ingredients that are part of the dish. This allows the robot to verify and update the state of each ingredient in relation to the dish being assembled, ensuring that all necessary conditions are met for the dish to be considered prepared.

- **plate-dish:** The robot plates a prepared dish in the serving room. Parameters include a robot, a room, and a dish. Preconditions require the room to be designated

for serving, the robot to be in the serving room, the robot to hold the dish, and the dish to be prepared. The effect is that the dish becomes served, and the robot is no longer holding the dish.

- **clean-tool:** The robot cleans a tool in the dishwashing room. Parameters include a robot, a tool, and a room. Preconditions require the robot to be in the dishwashing room, holding the tool, and the tool not being clean. The effect is that the tool becomes clean.

3 Results

3.1 Problem 1

3.1.1 Objects and Initial State

In this problem, we have five rooms: storage-room preparation-room cooking-room serving-room dishwashing-room cutting-room. The tools are a knife and a spatula and, at the start, both are clean and at their respective rooms. The ingredients are rice, fish, and vegetables and the desired state would be to have a sushi dish served and every tool clean and on its place. The recipe for sushi is the following:

Sushi

- Ingredients: rice, fish, vegetables.
- Conditions: rice must be cooked and fish and vegetables must be prepared.

3.1.2 Plan and Metrics

To see the whole plan see annex A.1. The plan has a total of 77 actions, it is correct, and the chef robot is able to prepare the sushi dish. The metrics of the found plan, using BFS Planner, are:

- **Nodes generated during search:** 1733
- **Nodes expanded during search:** 598
- **Plan found with cost:** 92
- **BFS search completed in:** 0.011774 seconds

3.2 Problem 2

3.2.1 Objects and Initial State

In this problem, we use the same rooms and tools as in the other problems. On the other hand, the dishes required are paella and sushi, not just sushi. In the initial state we now present two different recepies with their respective ingredients and conditions.

Paella

- Ingredients: rice, vegetables, fish, shrimps.
- Conditions: every ingredient must be cooked.

Sushi

- Ingredients: rice, fish, vegetables.
- Conditions: rice must be cooked and fish and vegetables must be prepared.

Besides this, at the start the knife is in the cooking room and the spatula is not clean. In this sense, the chef robot must clean the spatula before using it and move the knife to the cutting room.

3.2.2 Plan and Metrics

To see the whole plan see annex A.2. The plan has a total of 179 actions, it is correct, and the chef robot is able to prepare the two dishes. The metrics of the found plan, using BFS Planner, are:

- Nodes generated during search: 4289
- Nodes expanded during search: 1382
- Plan found with cost: 179
- BFS search completed in: 0.051842 seconds

4 Discussion

Discuss the results, their implications, and any limitations of the project.

5 Conclusion

Summarize the project, its outcomes, and potential future work.

6 References

A Planning Output

A.1 Problem 1

```
1 move chef cooking-room preparation-room
2 move chef preparation-room mixing-room
3 move chef mixing-room storage-room
4 pick-up-ingredient chef fish sushi storage-room
5 move chef storage-room cutting-room
6 drop-ingredient-at-prep chef fish cutting-room
7 pick-up chef knife cutting-room
8 prepare-ingredient chef fish knife cutting-room
9 move chef cutting-room mixing-room
10 move chef mixing-room preparation-room
11 move chef preparation-room dishwashing-room
12 clean-tool chef knife dishwashing-room
13 move chef dishwashing-room preparation-room
```

```
14 move chef preparation-room mixing-room
15 move chef mixing-room cutting-room
16 drop-tool chef knife cutting-room
17 move chef cutting-room storage-room
18 pick-up-ingredient chef vegetable sushi storage-room
19 move chef storage-room cutting-room
20 drop-ingredient-at-prep chef vegetable cutting-room
21 pick-up chef fish cutting-room
22 move chef cutting-room mixing-room
23 move chef mixing-room preparation-room
24 drop-ingredient-at-prep chef fish preparation-room
25 move chef preparation-room mixing-room
26 move chef mixing-room cutting-room
27 pick-up chef knife cutting-room
28 prepare-ingredient chef vegetable knife cutting-room
29 drop-tool chef knife cutting-room
30 move chef cutting-room storage-room
31 pick-up-ingredient chef rice sushi storage-room
32 move chef storage-room mixing-room
33 drop-ingredient-at-prep chef rice mixing-room
34 pick-up chef spatula mixing-room
35 prepare-ingredient chef rice spatula mixing-room
36 drop-tool chef spatula mixing-room
37 pick-up chef rice mixing-room
38 move chef mixing-room preparation-room
39 drop-ingredient-at-prep chef rice preparation-room
40 move chef preparation-room mixing-room
41 move chef mixing-room cutting-room
42 pick-up chef vegetable cutting-room
43 move chef cutting-room mixing-room
44 move chef mixing-room preparation-room
45 drop-ingredient-at-prep chef vegetable preparation-room
46 pick-up chef rice preparation-room
47 move chef preparation-room cooking-room
48 cook-ingredient chef rice cooking-room
49 move chef cooking-room preparation-room
50 drop-ingredient-at-prep chef rice preparation-room
51 move chef preparation-room mixing-room
52 pick-up chef spatula mixing-room
53 move chef mixing-room preparation-room
54 move chef preparation-room dishwashing-room
55 clean-tool chef spatula dishwashing-room
56 move chef dishwashing-room preparation-room
57 move chef preparation-room mixing-room
58 drop-tool chef spatula mixing-room
59 move chef mixing-room preparation-room
60 pick-up chef rice preparation-room
61 move chef preparation-room mixing-room
62 drop-ingredient-at-prep chef rice mixing-room
63 move chef mixing-room preparation-room
64 pick-up chef fish preparation-room
65 move chef preparation-room cooking-room
66 cook-ingredient chef fish cooking-room
67 move chef cooking-room preparation-room
68 move chef preparation-room mixing-room
69 move chef mixing-room cutting-room
70 drop-ingredient-at-prep chef fish cutting-room
71 pick-up chef knife cutting-room
```

```

72 move chef cutting-room mixing-room
73 move chef mixing-room preparation-room
74 move chef preparation-room dishwashing-room
75 clean-tool chef knife dishwashing-room
76 move chef dishwashing-room preparation-room
77 move chef preparation-room mixing-room
78 move chef mixing-room cutting-room
79 drop-tool chef knife cutting-room
80 pick-up chef fish cutting-room
81 move chef cutting-room mixing-room
82 move chef mixing-room preparation-room
83 drop-ingredient-at-prep chef fish preparation-room
84 move chef preparation-room mixing-room
85 pick-up chef rice mixing-room
86 move chef mixing-room preparation-room
87 drop-ingredient-at-prep chef rice preparation-room
88 assemble-dish chef sushi preparation-room
89 pick-up chef sushi preparation-room
90 move chef preparation-room cooking-room
91 move chef cooking-room serving-room
92 plate-dish chef serving-room sushi

```

Listing 1: Plan for Problem 1

A.2 Problem 2

```

1 move chef cooking-room preparation-room
2 move chef preparation-room mixing-room
3 pick-up chef spatula mixing-room
4 move chef mixing-room preparation-room
5 move chef preparation-room dishwashing-room
6 clean-tool chef spatula dishwashing-room
7 move chef dishwashing-room preparation-room
8 move chef preparation-room mixing-room
9 drop-tool chef spatula mixing-room
10 move chef mixing-room storage-room
11 pick-up-ingredient chef vegetable PAELLA storage-room
12 move chef storage-room cutting-room
13 drop-ingredient-at-prep chef vegetable cutting-room
14 move chef cutting-room storage-room
15 pick-up-ingredient chef shrimps PAELLA storage-room
16 move chef storage-room cutting-room
17 drop-ingredient-at-prep chef shrimps cutting-room
18 move chef cutting-room storage-room
19 pick-up-ingredient chef fish PAELLA storage-room
20 move chef storage-room cutting-room
21 drop-ingredient-at-prep chef fish cutting-room
22 move chef cutting-room storage-room
23 pick-up-ingredient chef fish1 sushi storage-room
24 move chef storage-room cutting-room
25 drop-ingredient-at-prep chef fish1 cutting-room
26 move chef cutting-room storage-room
27 pick-up-ingredient chef vegetable1 sushi storage-room
28 move chef storage-room cutting-room
29 drop-ingredient-at-prep chef vegetable1 cutting-room
30 move chef cutting-room storage-room
31 pick-up-ingredient chef rice PAELLA storage-room

```

```

32 move chef storage-room mixing-room
33 drop-ingredient-at-prep chef rice mixing-room
34 pick-up chef spatula mixing-room
35 prepare-ingredient chef rice spatula mixing-room
36 move chef mixing-room preparation-room
37 move chef preparation-room dishwashing-room
38 clean-tool chef spatula dishwashing-room
39 move chef dishwashing-room preparation-room
40 move chef preparation-room mixing-room
41 drop-tool chef spatula mixing-room
42 move chef mixing-room storage-room
43 pick-up-ingredient chef rice1 sushi storage-room
44 move chef storage-room mixing-room
45 drop-ingredient-at-prep chef rice1 mixing-room
46 pick-up chef rice mixing-room
47 move chef mixing-room preparation-room
48 drop-ingredient-at-prep chef rice preparation-room
49 move chef preparation-room mixing-room
50 pick-up chef spatula mixing-room
51 prepare-ingredient chef rice1 spatula mixing-room
52 move chef mixing-room preparation-room
53 move chef preparation-room dishwashing-room
54 clean-tool chef spatula dishwashing-room
55 move chef dishwashing-room preparation-room
56 move chef preparation-room mixing-room
57 drop-tool chef spatula mixing-room
58 pick-up chef rice1 mixing-room
59 move chef mixing-room preparation-room
60 drop-ingredient-at-prep chef rice1 preparation-room
61 move chef preparation-room cooking-room
62 pick-up chef knife cooking-room
63 move chef cooking-room preparation-room
64 move chef preparation-room mixing-room
65 move chef mixing-room cutting-room
66 prepare-ingredient chef fish1 knife cutting-room
67 drop-tool chef knife cutting-room
68 pick-up chef fish1 cutting-room
69 move chef cutting-room mixing-room
70 move chef mixing-room preparation-room
71 drop-ingredient-at-prep chef fish1 preparation-room
72 pick-up chef rice1 preparation-room
73 move chef preparation-room cooking-room
74 cook-ingredient chef rice1 cooking-room
75 move chef cooking-room preparation-room
76 drop-ingredient-at-prep chef rice1 preparation-room
77 pick-up chef rice preparation-room
78 move chef preparation-room cooking-room
79 cook-ingredient chef rice cooking-room
80 move chef cooking-room preparation-room
81 drop-ingredient-at-prep chef rice preparation-room
82 move chef preparation-room mixing-room
83 move chef mixing-room cutting-room
84 pick-up chef knife cutting-room
85 move chef cutting-room mixing-room
86 move chef mixing-room preparation-room
87 move chef preparation-room dishwashing-room
88 clean-tool chef knife dishwashing-room
89 move chef dishwashing-room preparation-room

```



```
90 move chef preparation-room mixing-room
91 move chef mixing-room cutting-room
92 prepare-ingredient chef vegetable1 knife cutting-room
93 drop-tool chef knife cutting-room
94 pick-up chef vegetable1 cutting-room
95 move chef cutting-room mixing-room
96 move chef mixing-room preparation-room
97 drop-ingredient-at-prep chef vegetable1 preparation-room
98 assemble-dish chef sushi preparation-room
99 pick-up chef sushi preparation-room
100 move chef preparation-room cooking-room
101 move chef cooking-room serving-room
102 plate-dish chef serving-room sushi
103 move chef serving-room cooking-room
104 move chef cooking-room preparation-room
105 move chef preparation-room mixing-room
106 move chef mixing-room cutting-room
107 pick-up chef knife cutting-room
108 move chef cutting-room mixing-room
109 move chef mixing-room preparation-room
110 move chef preparation-room dishwashing-room
111 clean-tool chef knife dishwashing-room
112 move chef dishwashing-room preparation-room
113 move chef preparation-room mixing-room
114 move chef mixing-room cutting-room
115 prepare-ingredient chef fish knife cutting-room
116 drop-tool chef knife cutting-room
117 pick-up chef fish cutting-room
118 move chef cutting-room mixing-room
119 move chef mixing-room preparation-room
120 move chef preparation-room cooking-room
121 cook-ingredient chef fish cooking-room
122 move chef cooking-room preparation-room
123 drop-ingredient-at-prep chef fish preparation-room
124 move chef preparation-room mixing-room
125 move chef mixing-room cutting-room
126 pick-up chef knife cutting-room
127 move chef cutting-room mixing-room
128 move chef mixing-room preparation-room
129 move chef preparation-room dishwashing-room
130 clean-tool chef knife dishwashing-room
131 move chef dishwashing-room preparation-room
132 move chef preparation-room mixing-room
133 move chef mixing-room cutting-room
134 prepare-ingredient chef vegetable knife cutting-room
135 drop-tool chef knife cutting-room
136 pick-up chef vegetable cutting-room
137 move chef cutting-room mixing-room
138 move chef mixing-room preparation-room
139 move chef preparation-room cooking-room
140 cook-ingredient chef vegetable cooking-room
141 move chef cooking-room preparation-room
142 drop-ingredient-at-prep chef vegetable preparation-room
143 move chef preparation-room mixing-room
144 move chef mixing-room cutting-room
145 pick-up chef knife cutting-room
146 move chef cutting-room mixing-room
147 move chef mixing-room preparation-room
```

```
148 move chef preparation-room dishwashing-room
149 clean-tool chef knife dishwashing-room
150 move chef dishwashing-room preparation-room
151 move chef preparation-room mixing-room
152 move chef mixing-room cutting-room
153 prepare-ingredient chef shrimps knife cutting-room
154 drop-tool chef knife cutting-room
155 pick-up chef shrimps cutting-room
156 move chef cutting-room mixing-room
157 move chef mixing-room preparation-room
158 move chef preparation-room cooking-room
159 cook-ingredient chef shrimps cooking-room
160 move chef cooking-room preparation-room
161 drop-ingredient-at-prep chef shrimps preparation-room
162 assemble-dish chef PAELLA preparation-room
163 move chef preparation-room mixing-room
164 move chef mixing-room cutting-room
165 pick-up chef knife cutting-room
166 move chef cutting-room mixing-room
167 move chef mixing-room preparation-room
168 move chef preparation-room dishwashing-room
169 clean-tool chef knife dishwashing-room
170 move chef dishwashing-room preparation-room
171 move chef preparation-room mixing-room
172 move chef mixing-room cutting-room
173 drop-tool chef knife cutting-room
174 move chef cutting-room mixing-room
175 move chef mixing-room preparation-room
176 pick-up chef PAELLA preparation-room
177 move chef preparation-room cooking-room
178 move chef cooking-room serving-room
179 plate-dish chef serving-room PAELLA
```

Listing 2: Plan for Problem 2