

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 automate meal preparation in a structured kitchen environment using a planning algorithm implemented in PDDL. For this project, we utilized the Best First Width Search (BFWS) planner to enable the robot to handle various recipes—such as tortilla, sushi, and paella—each requiring specific preparation steps across different kitchen zones. The task begins with a scenario where tools are misplaced and dirty, requiring the robot to clean, relocate, and organize the tools before proceeding with tasks like cutting, cooking, and mixing to prepare the ingredients.

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1 Introduction

Provide an introduction to the project, including background information and objectives.

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.

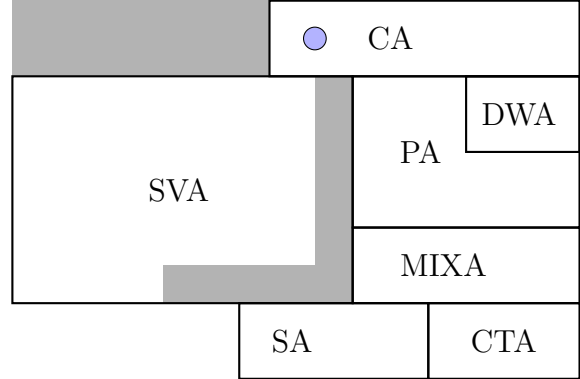


Figure 1: Kitchen layout

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

- (adjacent ?room1 - room ?room2 - room): *Room* **?room1** is adjacent to *room* **?room2**.
- (dish-prepared ?dish - dish): The *dish* **?dish** has been prepared.
- (dish-served ?dish - dish): The *dish* **?dish** has been served.
- (prioritize ?dish1 ?dish2): *Dish* **?dish1** has higher priority than *dish* **?dish2**.
- (is-storage ?room - room): *Room* **?room** functions as a storage area.
- (is-cooking ?room - room): *Room* **?room** is designated for cooking activities.
- (is-serving ?room - room): *Room* **?room** is designated for serving activities.
- (is-preparation ?room - room): *Room* **?room** is designated for preparation activities.
- (is-dishwashing ?room - room): *Room* **?room** is designated for dishwashing activities.
- (tool-use-room ?tool - tool ?room - room): The *tool* **?tool** is used in *room* **?room**.
- (ingredient-prep-room ?ingredient - ingredient ?room - room): The *ingredient* **?ingredient** is prepared in *room* **?room**.
- (ingredient-stored ?ingredient - ingredient): The *ingredient* **?ingredient** is stored.
- (ingredient-available ?ingredient - ingredient): The *ingredient* **?ingredient** is available for use.
- (ingredient-prepared ?ingredient - ingredient): The *ingredient* **?ingredient** has been prepared.
- (ingredient-cooked ?ingredient - ingredient): The *ingredient* **?ingredient** has been cooked.
- (ingredient-in-dish ?ingredient - ingredient ?dish - dish): The *ingredient* **?ingredient** is included in the *dish* **?dish**.
- (require-prepared ?dish - dish ?ingredient - ingredient): The *dish* **?dish** requires the *ingredient* **?ingredient** to be prepared.
- (require-cooked ?dish - dish ?ingredient - ingredient): The *dish* **?dish** requires the *ingredient* **?ingredient** to be cooked.

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 92 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 tee 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

3.3 Problem 3

3.3.1 Objects and Initial State

In this problem, we now have three recipes to prepare: tortilla, sushi, and paella. The recipes for sushi and paella remain the same as before, but we have added the tortilla, which requires specific ingredients: eggs, potatoes, and onions.

Tortilla

- Ingredients: eggs, potatoes, onions.
- Conditions: potatoes and onions must be cut first and then cooked.

The objective of this test is to evaluate what happens when there are multiple recipes and everything is out of place. The robot starts in the dishwashing room, and both tools—the spatula and the knife—are dirty and located in the wrong room (the service room).

3.3.2 Plan and Metrics

To see the whole plan see annex A.3. The plan has a total of 283 actions, it is correct, and the chef robot is able to prepare the three dishes. The metrics of the found plan, using BFS Planner, are:

- **Nodes generated during search:** 45145
- **Nodes expanded during search:** 14424
- **Plan found with cost:** 283
- **BFS search completed in:** 0.748445 secs

4 Discussion

After looking for a while into each and every plan, we were not able to see any outrageous move that could be enhanced. Clearly, this is no scientific method to prove optimality, but it is a good indicator.

5 Discussion

After a thorough analysis of each plan, we did not identify any significant actions that could be improved. While this approach does not constitute a rigorous method for proving optimality, it serves as a valuable indicator.

Moreover, we observe that the first problem, involving one dish, is solved in 0.012 seconds. The second problem, with two dishes, requires 0.052 seconds, and the third problem, encompassing three dishes, takes 0.748 seconds to solve. The number of nodes generated and expanded also exhibits an exponential increase relative to the number of dishes. This serves as a clear illustration of how problem complexity affects the time and resources needed for resolution. As the number of dishes and ingredients increases, the number of actions the robot must perform and consider significantly enlarges the search space.

6 Future Work

- **Error Handling and Adaptability:** To enhance the robot's functionality, we could introduce scenarios requiring it to adapt to unexpected events like missing ingredients or equipment malfunctions. In PDDL, this could be achieved by defining additional predicates and actions that allow the robot to detect these issues and execute contingency plans, such as a function that lets the robot get more ingredients if some are missing or a function to repair a broken tool.
- **Integration with Real-Time Order Systems:** We could improve operational clarity by detailing how the robot interacts with digital order systems, focusing on real-time order prioritization and scheduling. In PDDL, this could involve creating predicates that assign a priority to each order based on factors like number of ingredients or cooking preconditions.

7 Conclusion

This project showed how to create a detailed planning model using PDDL for a robot chef working in a kitchen. By clearly defining its actions, rules, and key components, we built a flexible system that can handle different cooking and serving tasks. Apart from this, we detected a great increase in search time and resources with additional recipes, which gives more importance to the need for efficient planning algorithms and optimization techniques.

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
```

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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

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```
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
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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

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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

A.3 Problem 3

```

1 move chef dishwashing-room preparation-room
2 move chef preparation-room mixing-room

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```

3 move chef mixing-room storage-room
4 pick-up-ingredient chef rice sushi storage-room
5 move chef storage-room mixing-room
6 drop-ingredient-at-prep chef rice mixing-room
7 move chef mixing-room preparation-room
8 move chef preparation-room cooking-room
9 move chef cooking-room serving-room
10 pick-up chef knife serving-room
11 move chef serving-room cooking-room
12 move chef cooking-room preparation-room
13 move chef preparation-room mixing-room
14 move chef mixing-room cutting-room
15 drop-tool chef knife cutting-room
16 move chef cutting-room mixing-room
17 move chef mixing-room preparation-room
18 move chef preparation-room cooking-room
19 move chef cooking-room serving-room
20 pick-up chef spatula serving-room
21 move chef serving-room cooking-room
22 move chef cooking-room preparation-room
23 move chef preparation-room mixing-room
24 drop-tool chef spatula mixing-room
25 move chef mixing-room storage-room
26 pick-up-ingredient chef onions tortilla storage-room
27 move chef storage-room cutting-room
28 drop-ingredient-at-prep chef onions cutting-room
29 move chef cutting-room storage-room
30 pick-up-ingredient chef eggs tortilla storage-room
31 move chef storage-room mixing-room
32 drop-ingredient-at-prep chef eggs mixing-room
33 move chef mixing-room storage-room
34 pick-up-ingredient chef potatoes tortilla storage-room
35 move chef storage-room cutting-room
36 drop-ingredient-at-prep chef potatoes cutting-room
37 move chef cutting-room storage-room
38 pick-up-ingredient chef rice1 paella storage-room
39 move chef storage-room mixing-room
40 drop-ingredient-at-prep chef rice1 mixing-room
41 move chef mixing-room storage-room
42 pick-up-ingredient chef vegetable1 paella storage-room
43 move chef storage-room cutting-room
44 drop-ingredient-at-prep chef vegetable1 cutting-room
45 move chef cutting-room storage-room
46 pick-up-ingredient chef shrimps paella storage-room
47 move chef storage-room cutting-room
48 drop-ingredient-at-prep chef shrimps cutting-room
49 move chef cutting-room storage-room
50 pick-up-ingredient chef fish1 paella storage-room
51 move chef storage-room cutting-room
52 drop-ingredient-at-prep chef fish1 cutting-room
53 move chef cutting-room storage-room
54 pick-up-ingredient chef fish sushi storage-room
55 move chef storage-room cutting-room
56 drop-ingredient-at-prep chef fish cutting-room
57 move chef cutting-room storage-room
58 pick-up-ingredient chef vegetable sushi storage-room
59 move chef storage-room cutting-room
60 drop-ingredient-at-prep chef vegetable cutting-room

```

```
61 move chef cutting-room mixing-room
62 pick-up chef spatula mixing-room
63 move chef mixing-room preparation-room
64 move chef preparation-room dishwashing-room
65 clean-tool chef spatula dishwashing-room
66 move chef dishwashing-room preparation-room
67 move chef preparation-room mixing-room
68 prepare-ingredient chef rice spatula mixing-room
69 drop-tool chef spatula mixing-room
70 pick-up chef rice mixing-room
71 move chef mixing-room preparation-room
72 move chef preparation-room cooking-room
73 cook-ingredient chef rice cooking-room
74 move chef cooking-room preparation-room
75 drop-ingredient-at-prep chef rice preparation-room
76 move chef preparation-room mixing-room
77 pick-up chef spatula mixing-room
78 move chef mixing-room preparation-room
79 move chef preparation-room dishwashing-room
80 clean-tool chef spatula dishwashing-room
81 move chef dishwashing-room preparation-room
82 move chef preparation-room mixing-room
83 prepare-ingredient chef eggs spatula mixing-room
84 drop-tool chef spatula mixing-room
85 pick-up chef eggs mixing-room
86 move chef mixing-room preparation-room
87 move chef preparation-room cooking-room
88 cook-ingredient chef eggs cooking-room
89 move chef cooking-room preparation-room
90 drop-ingredient-at-prep chef eggs preparation-room
91 move chef preparation-room mixing-room
92 pick-up chef spatula mixing-room
93 move chef mixing-room preparation-room
94 move chef preparation-room dishwashing-room
95 clean-tool chef spatula dishwashing-room
96 move chef dishwashing-room preparation-room
97 move chef preparation-room mixing-room
98 prepare-ingredient chef rice1 spatula mixing-room
99 drop-tool chef spatula mixing-room
100 pick-up chef rice1 mixing-room
101 move chef mixing-room preparation-room
102 move chef preparation-room cooking-room
103 cook-ingredient chef rice1 cooking-room
104 move chef cooking-room preparation-room
105 drop-ingredient-at-prep chef rice1 preparation-room
106 move chef preparation-room mixing-room
107 move chef mixing-room cutting-room
108 pick-up chef knife cutting-room
109 move chef cutting-room mixing-room
110 move chef mixing-room preparation-room
111 move chef preparation-room dishwashing-room
112 clean-tool chef knife dishwashing-room
113 move chef dishwashing-room preparation-room
114 move chef preparation-room mixing-room
115 move chef mixing-room cutting-room
116 prepare-ingredient chef fish knife cutting-room
117 drop-tool chef knife cutting-room
118 pick-up chef fish cutting-room
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119 move chef cutting-room mixing-room
120 move chef mixing-room preparation-room
121 drop-ingredient-at-prep chef fish preparation-room
122 move chef preparation-room mixing-room
123 move chef mixing-room cutting-room
124 pick-up chef knife cutting-room
125 move chef cutting-room mixing-room
126 move chef mixing-room preparation-room
127 move chef preparation-room dishwashing-room
128 clean-tool chef knife dishwashing-room
129 move chef dishwashing-room preparation-room
130 move chef preparation-room mixing-room
131 move chef mixing-room cutting-room
132 prepare-ingredient chef vegetable knife cutting-room
133 drop-tool chef knife cutting-room
134 pick-up chef vegetable cutting-room
135 move chef cutting-room mixing-room
136 move chef mixing-room preparation-room
137 drop-ingredient-at-prep chef vegetable preparation-room
138 assemble-dish chef sushi preparation-room
139 pick-up chef sushi preparation-room
140 move chef preparation-room cooking-room
141 move chef cooking-room serving-room
142 plate-dish chef serving-room sushi
143 move chef serving-room cooking-room
144 move chef cooking-room preparation-room
145 move chef preparation-room mixing-room
146 move chef mixing-room cutting-room
147 pick-up chef knife cutting-room
148 move chef cutting-room mixing-room
149 move chef mixing-room preparation-room
150 move chef preparation-room dishwashing-room
151 clean-tool chef knife dishwashing-room
152 move chef dishwashing-room preparation-room
153 move chef preparation-room mixing-room
154 move chef mixing-room cutting-room
155 prepare-ingredient chef potatoes knife cutting-room
156 drop-tool chef knife cutting-room
157 pick-up chef potatoes cutting-room
158 move chef cutting-room mixing-room
159 move chef mixing-room preparation-room
160 move chef preparation-room cooking-room
161 cook-ingredient chef potatoes cooking-room
162 move chef cooking-room preparation-room
163 drop-ingredient-at-prep chef potatoes preparation-room
164 move chef preparation-room mixing-room
165 move chef mixing-room cutting-room
166 pick-up chef knife cutting-room
167 move chef cutting-room mixing-room
168 move chef mixing-room preparation-room
169 move chef preparation-room dishwashing-room
170 clean-tool chef knife dishwashing-room
171 move chef dishwashing-room preparation-room
172 move chef preparation-room mixing-room
173 move chef mixing-room cutting-room
174 prepare-ingredient chef onions knife cutting-room
175 drop-tool chef knife cutting-room
176 pick-up chef onions cutting-room

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177 move chef cutting-room mixing-room
178 move chef mixing-room preparation-room
179 move chef preparation-room cooking-room
180 cook-ingredient chef onions cooking-room
181 move chef cooking-room preparation-room
182 drop-ingredient-at-prep chef onions preparation-room
183 assemble-dish chef tortilla preparation-room
184 pick-up chef tortilla preparation-room
185 move chef preparation-room cooking-room
186 move chef cooking-room serving-room
187 plate-dish chef serving-room tortilla
188 move chef serving-room cooking-room
189 move chef cooking-room preparation-room
190 move chef preparation-room mixing-room
191 move chef mixing-room cutting-room
192 pick-up chef knife cutting-room
193 move chef cutting-room mixing-room
194 move chef mixing-room preparation-room
195 move chef preparation-room dishwashing-room
196 clean-tool chef knife dishwashing-room
197 move chef dishwashing-room preparation-room
198 move chef preparation-room mixing-room
199 move chef mixing-room cutting-room
200 prepare-ingredient chef fish1 knife cutting-room
201 drop-tool chef knife cutting-room
202 pick-up chef fish1 cutting-room
203 move chef cutting-room mixing-room
204 move chef mixing-room preparation-room
205 move chef preparation-room cooking-room
206 cook-ingredient chef fish1 cooking-room
207 move chef cooking-room preparation-room
208 drop-ingredient-at-prep chef fish1 preparation-room
209 move chef preparation-room mixing-room
210 move chef mixing-room cutting-room
211 pick-up chef shrimps cutting-room
212 move chef cutting-room mixing-room
213 move chef mixing-room preparation-room
214 drop-ingredient-at-prep chef shrimps preparation-room
215 move chef preparation-room mixing-room
216 move chef mixing-room cutting-room
217 pick-up chef knife cutting-room
218 move chef cutting-room mixing-room
219 move chef mixing-room preparation-room
220 move chef preparation-room dishwashing-room
221 clean-tool chef knife dishwashing-room
222 move chef dishwashing-room preparation-room
223 move chef preparation-room mixing-room
224 move chef mixing-room cutting-room
225 prepare-ingredient chef vegetable1 knife cutting-room
226 drop-tool chef knife cutting-room
227 pick-up chef vegetable1 cutting-room
228 move chef cutting-room mixing-room
229 move chef mixing-room preparation-room
230 move chef preparation-room cooking-room
231 cook-ingredient chef vegetable1 cooking-room
232 move chef cooking-room preparation-room
233 drop-ingredient-at-prep chef vegetable1 preparation-room
234 pick-up chef shrimps preparation-room

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235 move chef preparation-room mixing-room
236 move chef mixing-room cutting-room
237 drop-ingredient-at-prep chef shrimps cutting-room
238 pick-up chef knife cutting-room
239 move chef cutting-room mixing-room
240 move chef mixing-room preparation-room
241 move chef preparation-room dishwashing-room
242 clean-tool chef knife dishwashing-room
243 move chef dishwashing-room preparation-room
244 move chef preparation-room mixing-room
245 move chef mixing-room cutting-room
246 prepare-ingredient chef shrimps knife cutting-room
247 drop-tool chef knife cutting-room
248 pick-up chef shrimps cutting-room
249 move chef cutting-room mixing-room
250 move chef mixing-room preparation-room
251 move chef preparation-room cooking-room
252 cook-ingredient chef shrimps cooking-room
253 move chef cooking-room preparation-room
254 drop-ingredient-at-prep chef shrimps preparation-room
255 assemble-dish chef paella preparation-room
256 pick-up chef paella preparation-room
257 move chef preparation-room cooking-room
258 move chef cooking-room serving-room
259 plate-dish chef serving-room paella
260 move chef serving-room cooking-room
261 move chef cooking-room preparation-room
262 move chef preparation-room mixing-room
263 move chef mixing-room cutting-room
264 pick-up chef knife cutting-room
265 move chef cutting-room mixing-room
266 move chef mixing-room preparation-room
267 move chef preparation-room dishwashing-room
268 clean-tool chef knife dishwashing-room
269 move chef dishwashing-room preparation-room
270 move chef preparation-room mixing-room
271 move chef mixing-room cutting-room
272 drop-tool chef knife cutting-room
273 move chef cutting-room mixing-room
274 pick-up chef spatula mixing-room
275 move chef mixing-room preparation-room
276 move chef preparation-room dishwashing-room
277 clean-tool chef spatula dishwashing-room
278 move chef dishwashing-room preparation-room
279 move chef preparation-room mixing-room
280 drop-tool chef spatula mixing-room
281 move chef mixing-room preparation-room
282 move chef preparation-room cooking-room
283 move chef cooking-room serving-room

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Listing 3: Plan for Problem 3