Anticipate & Collab: Supplementary Material

Contents

1 Tasks

1.1 Regular Tasks

We created a dataset of high-level tasks in a household environment.

- prepare breakfast (options = healthy_bf, junk)
- prepare lunch (options = healthy_l, junk)
- prepare dinner (options = healthy_d, junk)
- prepare medicines
- wash the dishes
- do the laundry
- serve the food
- prepare clothes (options = casual, formal, gym, party)
- charge the electronic devices
- prepare the office bag
- clean the room (room options = livingroom, kitchen, bathroom, storeroom) (object options = vacuum cleaner, mop)
- set up the office table
- throw away leftover food
- put remaining food in the fridge
- decorate the place
- serve a drink
- dust electronic devices
- extinguish the fire

1.2 Weekly Routine

We also created a dataset W of weekly routines. These routines are a sequence of tasks that are performed on specific days of the week. The dataset is defined as follows:

- **Monday:** Clean the bedroom, Prepare breakfast (Sandwich), Clean the bathroom, Prepare lunch (salad), Clean the kitchen, Wash the dishes, Prepare dinner (grilled salmon), Prepare medicines
- **Tuesday:** Clean the bedroom, Prepare breakfast (oatmeal), Prepare coffee, Prepare lunch (sandwich), Clean the bathroom, Clean the diningroom, Prepare dinner (chicken and rice), Prepare medicines
- **Wednesday:** Wash dirty clothes, Prepare breakfast (banana smoothie), Make the bed, Clean the Room (Pantry Room), Prepare lunch (soup), Prepare tea, Tend to the garden, Prepare dinner (veg stew), Clean the room (bedroom), Prepare medicines

- **Thursday:** Clean the office, Make the bed, Prepare tea, Prepare breakfast (boiled egg), Wash the dishes, Prepare lunch (mixed vegetable curry), Set up the office table, Prepare dinner (pasta), Prepare medicines
- **Friday:** Clean the diningroom, Prepare breakfast (oatmeal), Wash the clothes, Clean the kitchen, Prepare Lunch (Spaghetti), Clean the office, Wash the dishes, Prepare dinner (salmon), Prepare medicines
- **Saturday:** Tend to the garden, Clean the garden, Prepare tea, Prepare breakfast (scrambled egg), Clean the gym, Clean the office, Prepare lunch (soup), Wash the dishes, Repair the kitchen utensils, Prepare dinner (mixed vegetable curry), Prepare medicines

1.2.1 Illustrative Example

Let's examine a specific instance:

```
prompt = f'''
# The following tasks are possible in the household
tasks_sample_space = {task_sample_space}

# The following tasks were done in the last week:
task_last_week = {task_dict}

# For this week, these are the resources available:
Objects available: {objects}

# Input: Today is Wednesday
User Preference: All the dishes are dirty please clean them.
'''
```

The LLM gives the following output:

```
'chain of thought': "Following last Wednesday's routine. Add 'wash the dishes'
     as the 1st task to the task list, and keeping everything else the same."
'tasks' = [
    "Wash dirty dishes",
    "Wash dirty clothes",
    "Prepare breakfast (banana smoothie)",
    "Make the bed",
    "Clean the Room (Pantry Room)",
    "Prepare lunch (sandwich)",
    "Prepare dinner (veg stew)",
    "Clean the room (bedroom)",
    "Prepare medicines"
],
```

1.3 Resource Availability

In case of situations where the LLM is prompted to complete a task of cooking *pasta* for dinner on a specific day but the resource is not available, then LLM figures out and provides another option of cooking *Chicken and rice* based on the availability of the item. We illustrate the example below

1.3.1 Input Prompt:

```
prompt = f'''
# The following tasks are possible in the household
tasks_sample_space = {task_sample_space}

# The following tasks were done in the last week:
task_last_week = {task_dict}

# For this week, these are the resources available:
Objects available: {objects}

# Input: Today is Thursday, Based on the resources available, anticipate the
    tasks for the day
'''
```

1.3.2 Output LLM Prompt:

```
{
"chain of thought": "Following last Thursday's routine, Checking the resource
    availability. Last Thursday, boiled egg was made for breakfast. Boiled egg
    is available. Last Thursday, mixed vegetable curry was made for lunch.
    Mixed vegetable curry is available. Preparing mixed vegetable curry for
    lunch. Last Thursday, pasta was made for dinner. Pasta is NOT
    AVAILABLE. Preparing chicken and rice for dinner.",
"tasks": [
    "Clean the office",
    "Make the bed",
    "Prepare tea",
    "Prepare breakfast (boiled egg)",
    "Wash the dishes",
    "Prepare lunch (mixed vegetable curry)",
    "Set up the office table",
    "Prepare dinner (chicken and rice)",
    "Prepare medicines"
]
}
```

2 Cost Definition in Domain Description file

Actions	Cost
human_moves_br	Depends on human_dur
agent_moves_br	Depends on agent_dur
agent_pickup	20
agent_putdowns	20
human_picks	20
human_putdowns	20
human_picks_S	15
human_putdowns_S	15
agent_putdown	20
human_putdown	30
human_putdown_s	2
agent_picksUp_object	10
human_picksUp_object	20
agent_putsdown_object	10
human_putsdown_object	20
open	10
human_picksUp_freceptacle	5
human_putsdown_freceptacle	5
human_picksUp_receptacle	20
human_putsdown_receptacle	20
agent_picksUp_receptacle	10
agent_putsdown_receptacle	10
human_switches_on	15
agent_switches_on	10
human_switches_off	15
agent_switches_off	10
agent_switch_on	10
agent_switch_off	10
human_switch_on	10
human_switch_off	10
agent_cleans	25
human_cleans	75
agent_slice	15
human_slice	30
make_fruit_salad	80
human_cooks	50
agent_cooks	80
human_boils	30
agent_boils	15
human_roast	25
agent_roast	60
human_prepare_eggs	25
agent_prepare_eggs	80
agent_prepares_pizza_base	60

Actions	Cost
human_prepares_pizza_base	20
agent_bake_pizza	20
human_bake_pizza	60
agent_serves_pizza	20
human_serves_pizza	40
agent_serves_food	20
human_serves_food	40
agent_serves_fruit	20
human_serves_fruit	40
agent_serves_vegetable	20
human_serves_vegetable	40
bakeacake	90
agent_serves_baked	20
agent_serves_drink	20
human_serves_drink	10
remaining_food_cleaned	15
agent_washingdishes	30
human_washingdishes	10
agent_extinguish_fire	50
human_extinguish_fire	70
agent_washingclothes	40
human_washingclothes	60
agent_ironclothes	40
human_ironclothes	50
agent_foldclothes	30
human_foldclothes	50
laundry_done	10
agent_holds_vc_hose	10
human_holds_vc_hose	10
agent_starts_cleaning_	45
human_starts_cleaning_	50
agent_passes_to_human	5
agent_cleans_electronics	60
human_cleans_electronics	20
all_electronic_item_cleaned	0
house_cleaned	0
office_table_ready	0
agent_cleans_recepetacle	20
human_cleans_receptacle	25
prepare_office_bag	0
clothes_prepared	10
attached_for_charging	5
agent_provides_	5
party_starts	0

Table 1: Table of Cost defined for all type of actions performed by the human and the agent

The Table 1 mentions about the details regarding the costs considered for each action (for both the actors). The movement cost (not defined here) used in our domain is calculated by calculating the distance between the immobile receptacles in the environment which is then normalized to get the values between 0 and 100.

3 HRI collaborative plan

Here, we describe an example where human-robot collaborative plan was generated. We show an example from the experimental setting in which the human is faster than the agent and thus has a lower movement cost than the agent. To reach the below goal state:

```
(:goal
    (and
        (cleaned_remaining_food cooked_pasta)
        (served_drink milk glass_1 working_table livingroom)
   )
)
```

while trying to optimize the "cost" metric, we obtain the following plan with a cost of 582:

```
(agent_moves_br ironing_board stove_burner_1 livingroom kitchen)
(human_moves_br laundrybag fridge storeroom kitchen)
(human_picks milk fridge kitchen)
(human_moves_br fridge cabinet kitchen kitchen)
(human_picksup_freceptacle glass_1 cabinet kitchen)
(human_moves_br cabinet working_table kitchen livingroom)
(human_putsdown_freceptacle glass_1 working_table livingroom)
(human_putdowns milk working_table livingroom)
(human_serves_drink milk glass_1 working_table livingroom)
(agent_switches_on burner stove_burner_1 kitchen)
(human_moves_br working_table cabinet livingroom kitchen)
(human_picks pasta cabinet kitchen)
(human_moves_br cabinet rack kitchen kitchen)
(human_picksup_receptacle metal_pot rack kitchen)
(human_moves_br rack stove_burner_1 kitchen kitchen)
(human_putsdown_receptacle metal_pot stove_burner_1 kitchen)
(human_putdown pasta metal_pot stove_burner_1 kitchen)
(human_cooks pasta cooked_pasta)
(human_picks cooked_pasta stove_burner_1 kitchen)
(human_moves_br stove_burner_1 dustbin_1 kitchen kitchen)
(human_putdowns cooked_pasta dustbin_1 kitchen)
(remaining_food_cleaned cooked_pasta)
```

4 PDDL plans

Below, we will showcase examples of plans generated by our agent *with Adaptation* as well as those created without it.

1. **No adaptation plan - will change it later**

   - *Plan without adaptation*

```
(human_moves_br washingmachine shelf bathroom kitchen)
(human_picksup_freceptacle bowl_1 shelf kitchen)
(human_moves_br shelf fridge kitchen kitchen)
(agent_moves_br closet sink livingroom kitchen)
(human_picks potato fridge kitchen)
(human_picks avocado fridge kitchen)
(human_picks banana fridge kitchen)
(agent_switches_on faucet sink kitchen)
(human_moves_br fridge sink kitchen kitchen)
(human_putdowns avocado sink kitchen)
(agent_cleans avocado)
(human_picks avocado sink kitchen)
(human_putdowns banana sink kitchen)
(agent_cleans banana)
(human_picks banana sink kitchen)
(human_moves_br sink countertop kitchen kitchen)
(human_putsdown_freceptacle bowl_1 countertop kitchen)
(agent_moves_br sink countertop kitchen kitchen)
(human_putdowns avocado countertop kitchen)
(human_putdowns banana countertop kitchen)
(agent_slice avocado sliced_avocado)
(agent_slice banana sliced_banana)
(agent_pickup sliced_avocado countertop kitchen)
(agent_putdown sliced_avocado bowl_1 countertop kitchen)
(agent_pickup sliced_banana countertop kitchen)
(agent_putdown sliced_banana bowl_1 countertop kitchen)
(human_moves_br countertop fridge kitchen kitchen)
(human_picks apple fridge kitchen)
(human_moves_br fridge countertop kitchen kitchen)
```

- Original Plan with No Adaptation

```
(human_moves_br washingmachine shelf bathroom kitchen)
(human_picksup_freceptacle bowl_1 shelf kitchen)
(human_moves_br shelf fridge kitchen kitchen)
(agent_moves_br closet sink livingroom kitchen)
(human_picks potato fridge kitchen)
(human_picks avocado fridge kitchen)
(human_picks banana fridge kitchen)
(agent_switches_on faucet sink kitchen)
(human_moves_br fridge sink kitchen kitchen)
(human_putdowns apple sink kitchen) \\NOT_APPLICABLE
(agent_cleans apple) \\NOT_APPLICABLE
(human_picks apple sink kitchen) \\NOT_APPLICABLE
(human_putdowns avocado sink kitchen)
(agent_cleans avocado)
(human_picks avocado sink kitchen)
(human_putdowns banana sink kitchen)
(agent_cleans banana)
(human_picks banana sink kitchen)
(human_moves_br sink countertop kitchen kitchen)
(human_putsdown_freceptacle bowl_1 countertop kitchen)
(agent_moves_br sink countertop kitchen kitchen)
(human_putdowns apple countertop kitchen) \\NOT_APPLICABLE
(human_putdowns avocado countertop kitchen)
(human_putdowns banana countertop kitchen)
(agent_slice apple sliced_apple) \\NOT_APPLICABLE
(agent_slice avocado sliced_avocado)
(agent_slice banana sliced_banana)
(agent_pickup sliced_apple countertop kitchen) NOT_APPLICABLE
(agent_putdown sliced_apple bowl_1 countertop kitchen) \\NOT_APPLICABLE
(agent_pickup sliced_avocado countertop kitchen)
(agent_putdown sliced_avocado bowl_1 countertop kitchen)
(agent_pickup sliced_banana countertop kitchen)
(agent_putdown sliced_banana bowl_1 countertop kitchen)
(make_fruit_salad bowl_1 sliced_apple sliced_avocado sliced_banana fruit_salad) \\NOT_APPLI
(human_moves_br countertop fridge kitchen kitchen)
(human_picks apple fridge kitchen)
(human_moves_br fridge countertop kitchen kitchen)
; cost = 842 (general cost)
```

2. Action State Plan to be - Change it later+ (Adaptation Plan (copy)

- Plan with adaptation

```
(human_moves_br washingmachine shelf bathroom kitchen)
(human_picksup_freceptacle bowl_1 shelf kitchen)
(human_moves_br shelf fridge kitchen kitchen)
(agent_moves_br closet sink livingroom kitchen)
```

```
(human_picks potato fridge kitchen)
(human_putdowns potato fridge kitchen)
(human_picks apple fridge kitchen)
(human_picks avocado fridge kitchen)
(human_picks banana fridge kitchen)
(human_moves_br fridge countertop kitchen kitchen)
(human_putsdown_freceptacle bowl_1 countertop kitchen)
(agent_switches_on faucet sink kitchen)
(human_moves_br countertop sink kitchen kitchen)
(agent_moves_br sink countertop kitchen kitchen)
(human_putdowns apple sink kitchen)
(human_cleans apple)
(human_picks apple sink kitchen)
(human_putdowns avocado sink kitchen)
(human_cleans avocado)
(human_picks avocado sink kitchen)
(human_putdowns banana sink kitchen)
(human_cleans banana)
(human_picks banana sink kitchen)
(human_moves_br sink countertop kitchen kitchen)
(human_putdowns apple countertop kitchen)
(human_putdowns avocado countertop kitchen)
(human_putdowns banana countertop kitchen)
(agent_slice apple sliced_apple)
(human_picks sliced_apple countertop kitchen)
(human_putdown sliced_apple bowl_1 countertop kitchen)
(agent_slice avocado sliced_avocado)
(human_picks sliced_avocado countertop kitchen)
(human_putdown sliced_avocado bowl_1 countertop kitchen)
(agent_slice banana sliced_banana)
(human_picks sliced_banana countertop kitchen)
(human_putdown sliced_banana bowl_1 countertop kitchen)
(make_fruit_salad bowl_1 sliced_apple sliced_avocado sliced_banana fruit_salad)
```

- Ideal Adaptation Plan

```
(human_moves_br washingmachine shelf bathroom kitchen)
(human_picksup_freceptacle bowl_1 shelf kitchen)
(human_moves_br shelf fridge kitchen kitchen)
(agent_moves_br closet sink livingroom kitchen)
(human_picks apple fridge kitchen)
(human_picks avocado fridge kitchen)
(human_picks banana fridge kitchen)
(agent_switches_on faucet sink kitchen)
(human_moves_br fridge sink kitchen kitchen)
(human_putdowns apple sink kitchen)
(agent_cleans apple)
(human_picks apple sink kitchen)
(human_putdowns avocado sink kitchen)
(agent_cleans avocado)
```

```
(human_picks avocado sink kitchen)
(human_putdowns banana sink kitchen)
(agent_cleans banana)
(human_picks banana sink kitchen)
(human_moves_br sink countertop kitchen kitchen)
(human_putsdown_freceptacle bowl_1 countertop kitchen)
(agent_moves_br sink countertop kitchen kitchen)
(human_putdowns apple countertop kitchen)
(human_putdowns avocado countertop kitchen)
(human_putdowns banana countertop kitchen)
(agent_slice apple sliced_apple)
(agent_slice avocado sliced_avocado)
(agent_slice banana sliced_banana)
(agent_pickup sliced_apple countertop kitchen)
(agent_putdown sliced_apple bowl_1 countertop kitchen)
(agent_pickup sliced_avocado countertop kitchen)
(agent_putdown sliced_avocado bowl_1 countertop kitchen)
(agent_pickup sliced_banana countertop kitchen)
(agent_putdown sliced_banana bowl_1 countertop kitchen)
(make_fruit_salad bowl_1 sliced_apple sliced_avocado sliced_banana fruit_salad)
```

3. **Additional Instructions:**

- Required Preconditions:

```
- cleaned avocado
- cleaned apple
- cleaned banana
- sliced avocado
- sliced apple
- sliced banana
- receptacle_at bowl_1 countertop kitchen
- salad_prepared bowl_1 sliced_apple sliced_avocado sliced_banana
```

- Preconditions Met:

```
- cleaned avocado
- cleaned banana
- sliced avocado
- sliced banana
- receptacle_at bowl_1 countertop kitchen

Success % = 62.5%
```

5 Simulation Details

Figure 1: Our Domain Environment

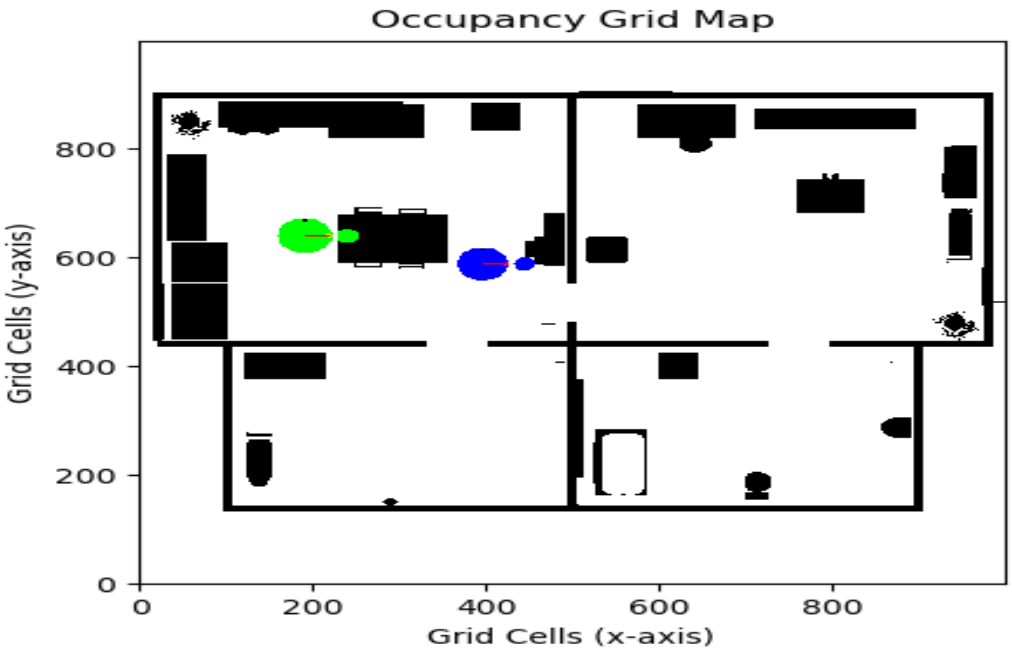

Figure 2: The tracking of human (represented in blue) and agent (represented in green) in the simulation environment

Fig. 1 is our customly made household environment in the Coppeliasim Simulator. Actions from the generated plan are fed to the actors via the Coppeliasim API, with action outcomes encoded in local child scripts provided by the simulator. Fig. 2 illustrates how the agent and the human are tracked in the simulation. This helps us in integrating the Collision avoidance stack.

6 Results

	ROBOT								
		Init →	Livingroom		Storeroom		Bathroom		Kitchen	
	Heuristics	Init ↓	ζ_{HFAS}	ζ_{AFHS}	ζ_{HFAS}	ζ_{AFHS}	ζ_{HFAS}	ζ_{AFHS}	ζ_{HFAS}	ζ_{AFHS}
H	seq-sat-fdss-2018 (90 sec)	Livingroom	1.143	1.171	1.09	**0.972**	1.058	1.134	1.063	1.009
U		Storeroom	1.155	1.066	1.238	1.135	1.149	1.149	1.167	1.185
M		Bathroom	1.196	1.108	1.162	1.053	1.203	1.126	1.23	1.163
A		Kitchen	1.202	1.105	1.169	1.025	1.139	1.045	1.176	1.112
N	seq-sat-fd-autotune-1 (90 sec)	Livingroom	1.039	**0.92**	1.016	**0.909**	0.906	**0.9**	0.806	**0.914**
		Storeroom	1.024	**0.987**	1.089	1.005	1.052	**0.997**	1.055	1.021
		Bathroom	1.013	**0.948**	1.043	**0.949**	1.067	**0.946**	1.025	**0.936**
		Kitchen	1.038	**0.982**	1.05	**0.981**	1.043	**0.968**	1.091	1.026

Table 2: Computed ζ as the ratio of execution time with collaboration over the execution time without collaboration. Each value in table is average over 50 trials (with two of more tasks in the goal state) for each of 16 possible initial locations of the agent and the human, and for each of two settings: HFAS and AFHS. Results indicate a clear benefit of human-agent collaboration in terms of reduction in execution time, thus supporting **H3**.

The Table 2 is an extension to the Hypothesis 3 in the paper. In short, we evaluate the execution cost between collaboration and no-collaboration scenario and claim that the collaboration between the human and the agent reduces the execution cost and leads to faster completion of tasks. We used different configurations provided by the *Fast-Downward* system namely *lama*, *seq-sat-fdss-2018* and *seq-sat-fd-autotune-1*. We observe that *lama* outperforms other aliases and here in the above table we showcase the results from different configurations.