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Problem 2. Reactive motion planning (20 points)

Consider an office with 7 rooms for work and one kitchen room. A robot has been entrusted with the responsibility of collecting used coffee mugs from the rooms and bring them to the kitchen. The robot can carry only one cup at a time. It keeps on visiting the rooms and if there is an empty cup in a room, it brings it to the kitchen. If it does not find a cup, it visits another room.

Capture the requirements stated above in the form of an LTL formula. Construct the layout of the office space based on the layout shown in Figure 2 in [KFP09], where region 1 is the kitchen and region 2-8 are the office rooms. Then with the help of LTLMoP tool, synthesize a reactive controller for the robot and simulate its behavior.

[KFP09] H. Kress-Gazit, G. E. Fainekos, and G. J. Pappas. Temporal-logic-based reactive mission and motion planning. IEEE Transactions on Robotics, 25(6):1370-1381, 2009.

Submit the following:

- Specification using LTL symbols.
- Specification in LTLMoP syntax.
- Synthesized Controller.
- Snapshot of the trajectories.

LTLMoP Webpage: `https://ltlmop.github.io`

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Specification with LTL symbols.

Workspace P is partitioned into $P_1, P_2, \dots P_{13}$,

Boolean proposition $\{r_1, r_2, \dots r_{12}\}$ which are true if robot is located at P_i else false

where P_1 : kitchen $P_2, \dots P_8$: Work room

$P_9, \dots P_{12}$: pathway.

Action proposition (Boolean) $A = \{a^{pickup}, a^{carry}, a^{drop}\}$ which are true if such actions are executed else false

sensor proposition $X = \{s^{cup}\}$

~~Robot proposition~~ $\cancel{Y = r_1, r_2, \dots r}$

LTL $\varphi = \varphi_e \Rightarrow \varphi_s$; e - environment proposition , s - sensor proportion.

where as $\varphi_e = \varphi_i^e \wedge \varphi_t^e \wedge \varphi_g^e$

$\varphi_s = \varphi_i^s \wedge \varphi_t^s \wedge \varphi_g^s$

$\varphi_i^e = \{\neg s^{cup}\}$ i : initial value.

$\neg$: negation.

Initially the sensor s^{cup} is set to false in envi

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$\varphi^e_t = \Box\Big((\neg r_2 \wedge \neg r_3 \wedge \neg r_4 \wedge \neg r_5 \wedge \neg r_6 \wedge \neg r_7 \wedge \neg r_8) \Rightarrow (\bigcirc s^{cup} \Leftrightarrow s^{cup})\Big)$

ie) other than work room, the value of s^{cup} won't change.

$\varphi^e_g = \Box\Diamond \text{True}$; g : goal

Completing the modeling of the environment assumptions.

$\varphi^s_i = \Big(r_1 \wedge (i \in 2, 3, \ldots 12)\ \neg r_i \wedge \neg a^{pickup} \wedge \neg a^{drop} \wedge \neg a^{carry}\Big)$

Initially robot starts in region r_1 with no action enabled.

φ^s_t (Models the possible changes in the robot state)

$$\varphi^s_t = \begin{cases} \wedge\ \Box(r_1 \Rightarrow \bigcirc r_9) \\ \wedge\ \Box(r_2 \Rightarrow \bigcirc r_{12}) \\ \wedge\ \Box(r_3 \Rightarrow \bigcirc r_{11}) \\ \wedge\ \Box(r_4 \Rightarrow \bigcirc r_{11}) \\ \wedge\ \Box(r_5 \Rightarrow \bigcirc r_{10}) \\ \wedge\ \Box(r_6 \Rightarrow \bigcirc r_{10}) \\ \wedge\ \Box(r_7 \Rightarrow \bigcirc r_{10}) \\ \wedge\ \Box(r_8 \Rightarrow \bigcirc r_9) \end{cases}$$

$\wedge\ \Box(r_9 \Rightarrow (\bigcirc r_1 \vee \bigcirc r_{12} \vee \bigcirc r_8 \vee \bigcirc r_{10}))$

$\wedge\ \Box(r_{10} \Rightarrow (\bigcirc r_9 \vee \bigcirc r_7 \vee \bigcirc r_6 \vee \bigcirc r_{11} \vee \bigcirc r_5))$

$\wedge\ \Box(r_{11} \Rightarrow (\bigcirc r_{12} \vee \bigcirc r_3 \vee \bigcirc r_4 \vee \bigcirc r_5 \vee \bigcirc r_{10}))$

$\wedge\ \Box(r_{12} \Rightarrow (\bigcirc r_9 \vee \bigcirc r_2 \vee \bigcirc r_{11}))$

→ Possible transition between regions

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cont.

$$\varphi_t^s = \begin{cases} \wedge \square ((\bigcirc s^{cup} \Rightarrow \bigcirc a^{pickup}) \Rightarrow \bigcirc a^{carry}) \Rightarrow \quad i \in 1,2,\dots 12 \\ \wedge \square ((r_1 \wedge a^{carry}) \Rightarrow \bigcirc a^{drop}) \\ \wedge \square (a^{drop} \Rightarrow \bigcirc \neg a^{carry}) \end{cases}$$

$\bigcirc r_i \Leftrightarrow \neg (r_2 \vee r_3 \vee r_4 \vee r_5 \vee r_6 \vee r_7 \vee r_8) \, \mathcal{U} \, r_1$

$$\varphi_g^s = \begin{cases} \square \lozenge (r_2 \vee s^{cup}) \wedge \square \lozenge (r_3 \vee s^{cup}) \wedge \square \lozenge (r_4 \vee s^{cup}). \\ \wedge \square \lozenge (r_5 \vee s^{cup}) \wedge \square \lozenge (r_6 \vee s^{cup}) \wedge \square \lozenge (r_7 \vee s^{cup}) \\ \wedge \square \lozenge (r_8 \vee s^{cup}) \end{cases}$$

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Specification using LTLMoP syntax

#Define Initial Config
Environment starts with false
Robot starts with false

#Define group
group rooms is r2,r3,r4,r5,r6,r7,r8

#Define visit
if you are not activating carry then visit all
rooms if you are in r1 then do not cup

#Define pickup
do pickup if and only if you are sensing cup and you are in any rooms and you are not activating carry

#Define carry
carry is set on pickup and reset on drop

#Define drop
if you are activating carry then visit r1 do drop if and only if you are in r1 and you are activating carry

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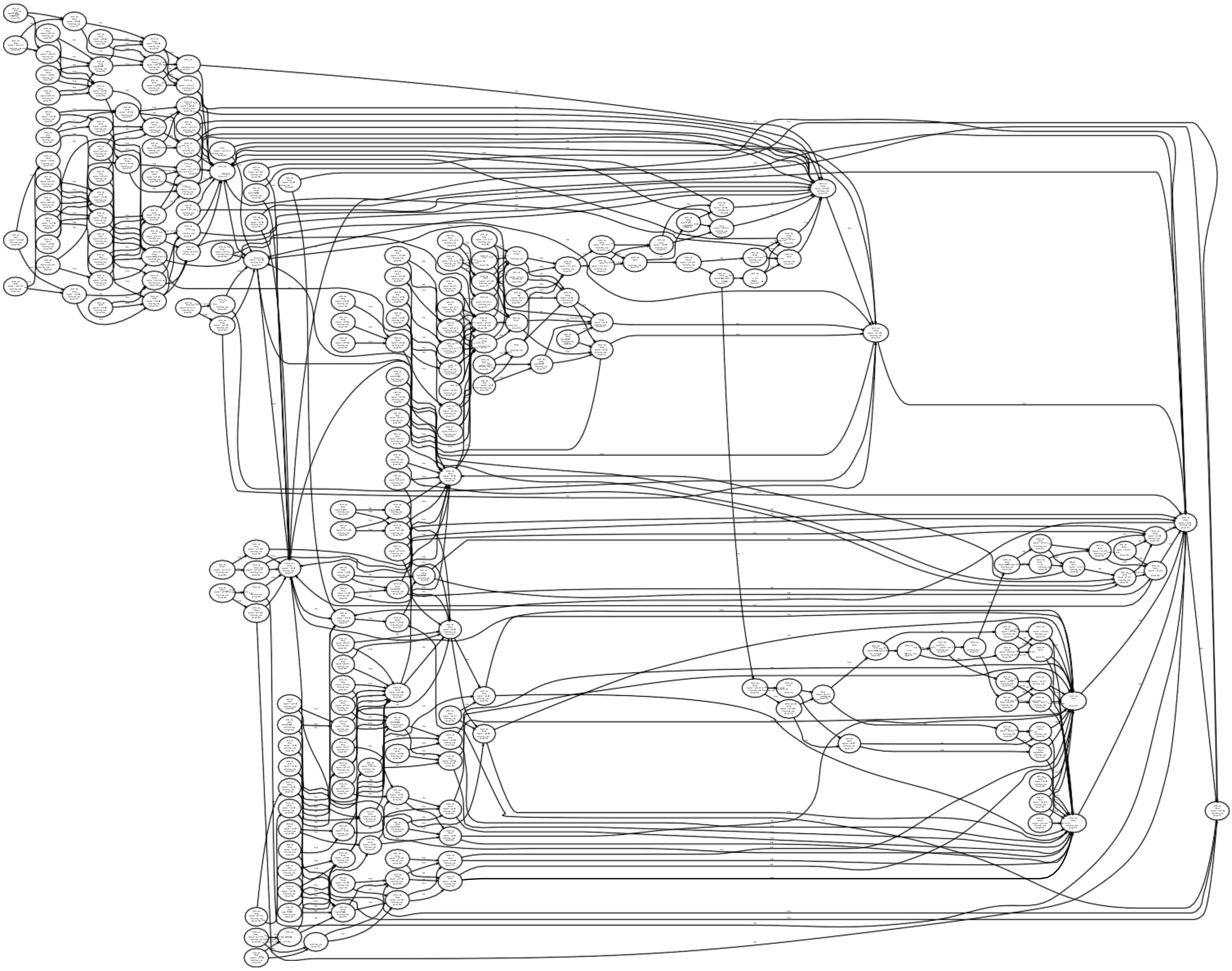
Synthesized Controller



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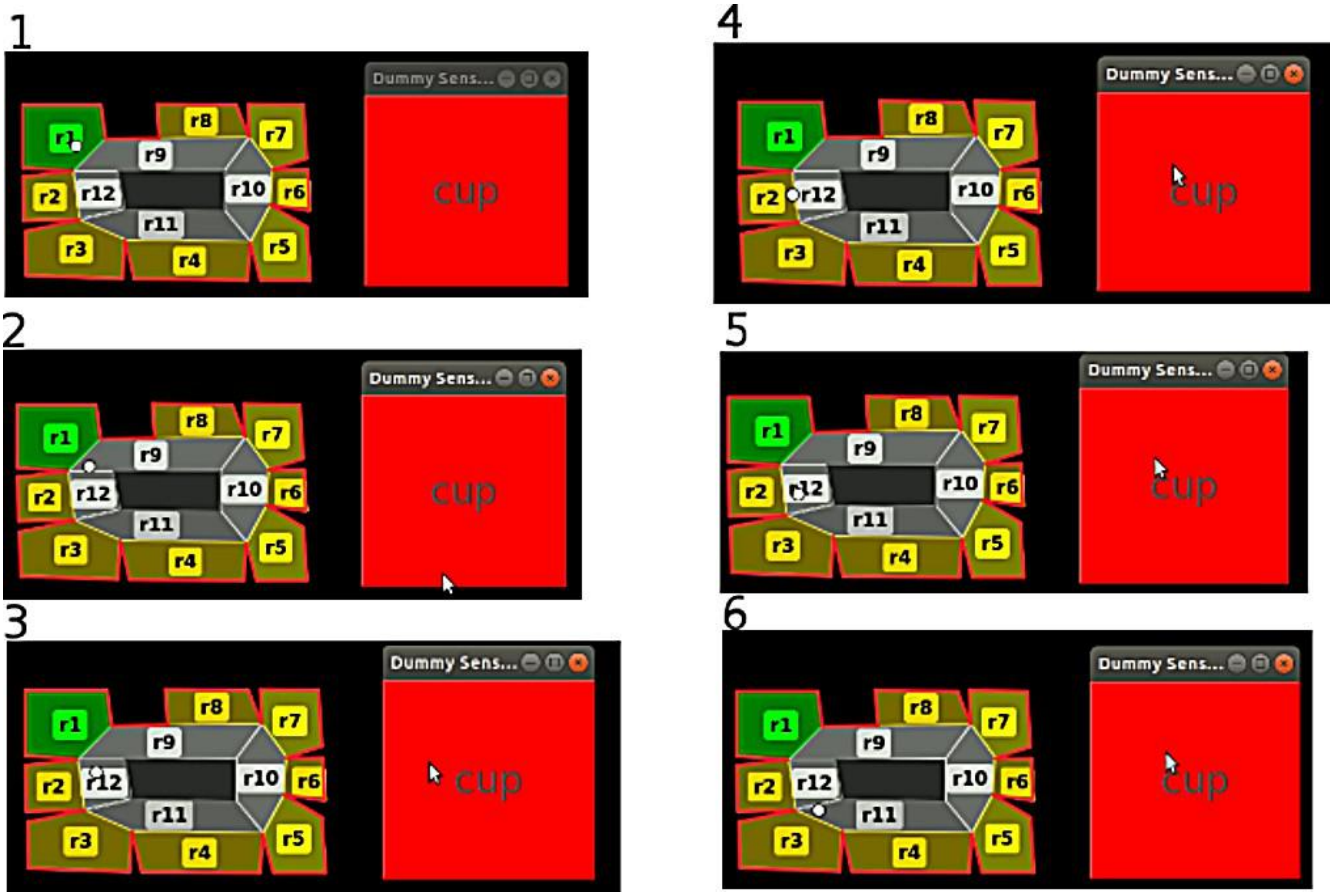

Fig 4: Part-1 Snapshot of the trajectory synthesized by LTLMoP Tool

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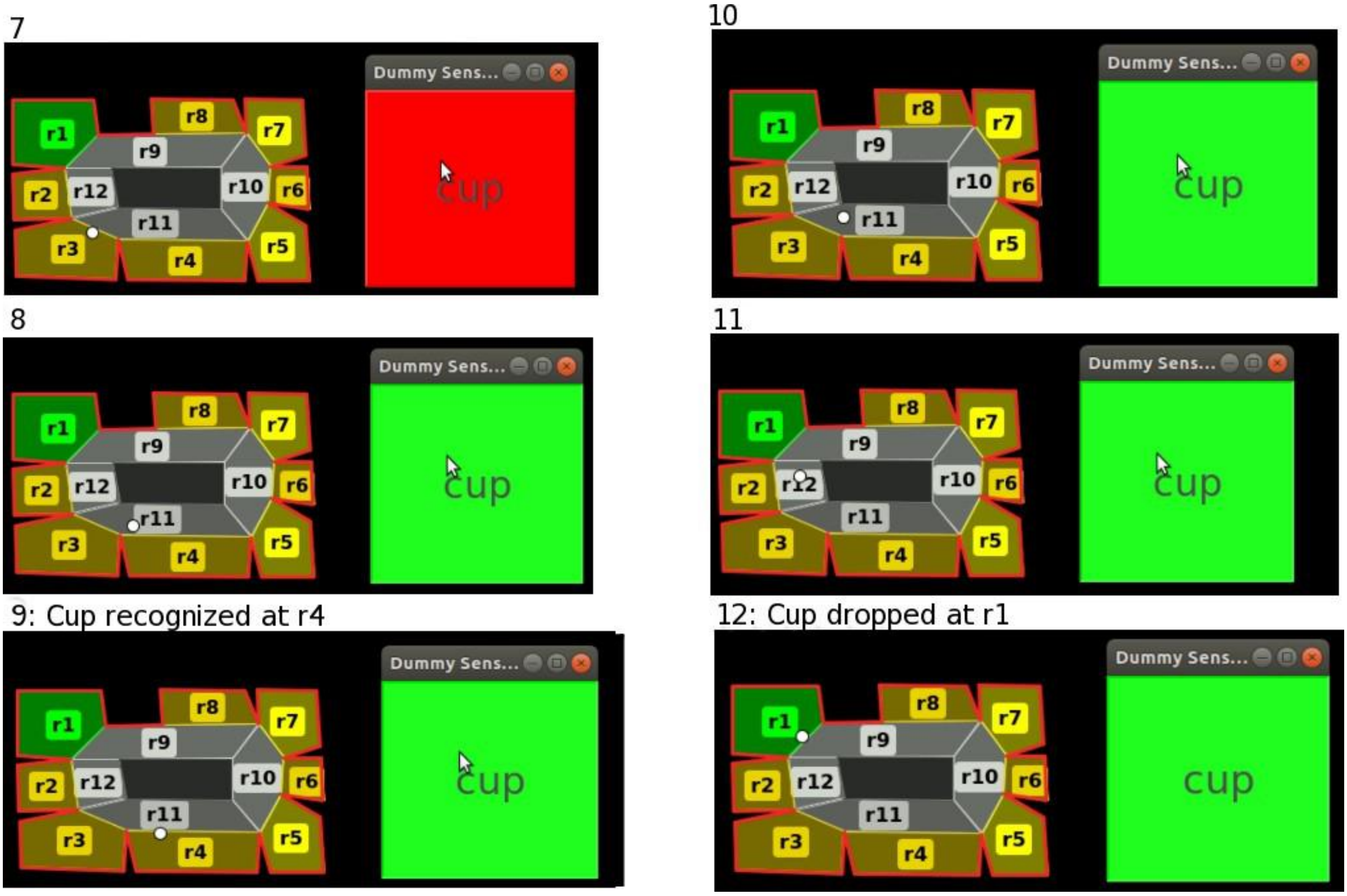
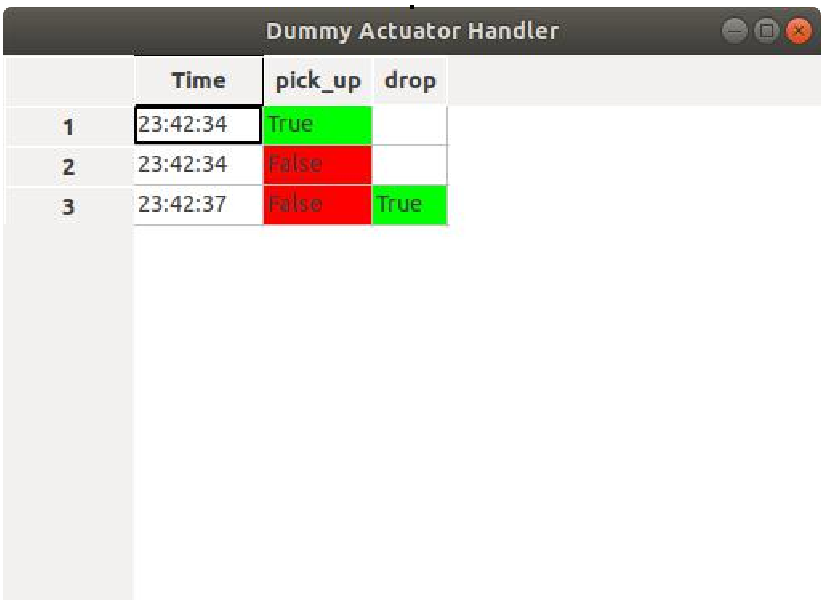


Fig 4: Part-2 Snapshot of the trajectory synthesized by LTLMoP Tool



Dummy Actuator Handler

	Time	pick_up	drop
1	23:42:34	True	
2	23:42:34	False	
3	23:42:37	False	True

Fig 5: Part-3 Snapshot of the Dummy Actuator handler