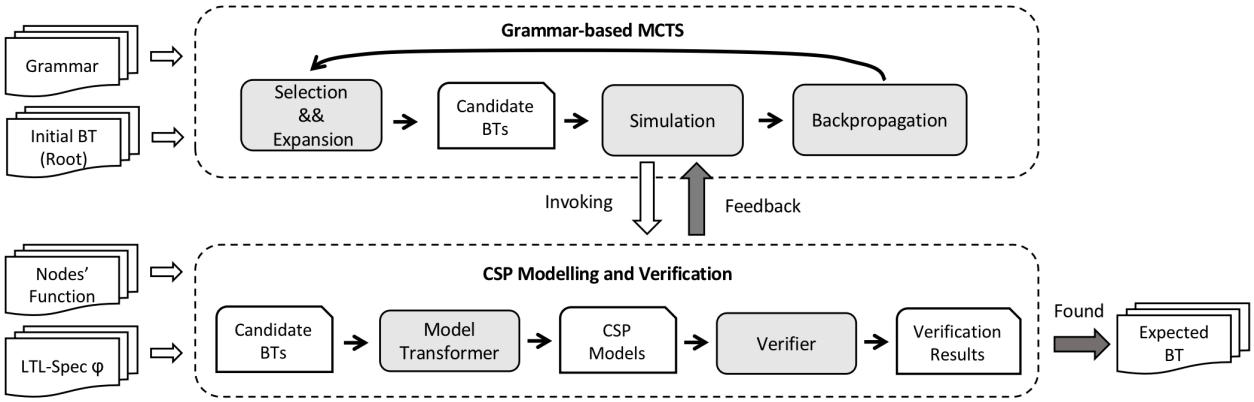
Formal Verification based Synthesis for Behavior Trees

- **The source code will be available later.**

Framework



1. Mission_charge

- **Mission Description**: The mission contains an unexpected influence factor ***LowBattery*** in the environment. The robot may navigate to the charging position if LowBattery is true or navigate to the destination position if LowBattery is false.

- **Available Nodes**:

  - $Action$: $GotoRechargingPos$, $GotoDestination$
  - $Condition$: $LowBattery$, $AtRechargingPos$, $AtDestinationPos$

- **Nodes' Function**:

Action	Requirement	Result
GotoRechargingPos	LowBattery, ¬AtRechargingPos	¬LowBattery, AtRechargingPos, ¬AtDestinationPos
GotoDestinationPos	¬LowBattery, ¬AtDestinationPos	¬AtRechargingPos, AtDestinationPos

- **Specification**:

$$\varphi = \mathcal{F}\,(LowBattery_s \ \vee \ LowBattery_f)$$

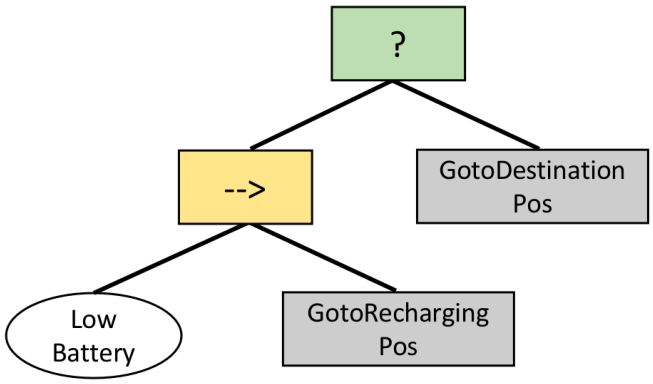
$$\wedge\, \mathcal{F}\,(AtRechargingPos_s \ \vee \ AtDestinationPos_s)$$

$$\wedge\, \mathcal{G}\,(LowBattery_s \rightarrow (\,(\neg GotoDestinationPos_s \ \mathcal{U} \ LowBattery_f) \ \vee \ \mathcal{G}\,\neg GotoDestinationPos_s\,)\,)$$

- **Run Information under MCTS with Verifier**:

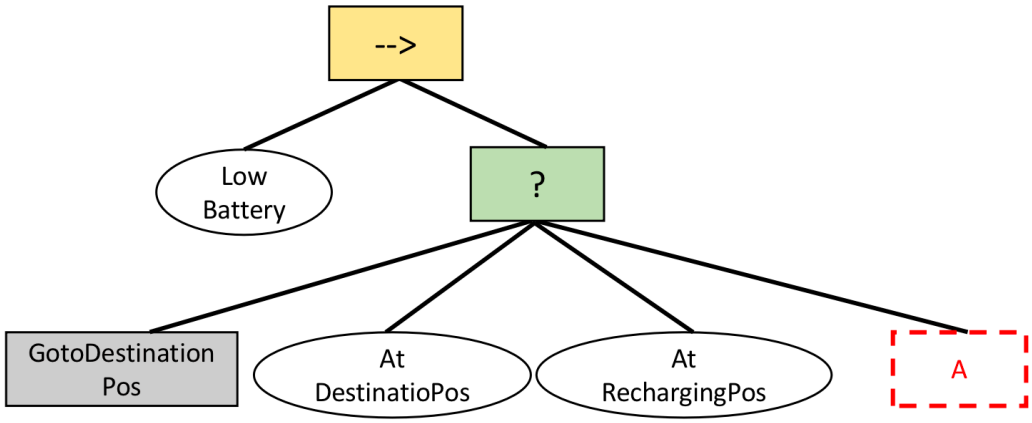
```
timecost:  173.69546008110046
verification time ratio:  1.2722 (220.98/173.7)
storing ratio:  0.879 (437[Verify]+544[NoVerify]/1116)
pruning ratio:  0.121 (35[Com-V]+44[Incom-V]+56[Incom-S]/1116)
pruning ratio in verification:  0.1531
```

- **Synthesized BT under MCTS with Verifier**:



MCTS with verifier

- **Synthesized BT under MCTS with Simulator (1 hour)**:



MCTS with simulator

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2. Mission_patrol$_1$

- **Mission Description**: The mission requires a robot to infinitely visit positions A, B, and C without an order.
- **Available Nodes**:
  - $Action: GotoA,\ GotoB,\ GotoC$
  - $Condition: VisitedA,\ VisitedB,\ VisitedC$
- **Nodes' Function**:

Action	Requirement	Result
GotoA	\	VisitedA
GotoB	\	VisitedB
GotoC	\	VisitedC

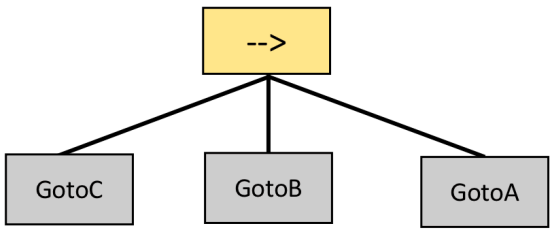
- **Specification**:

$$\varphi = \mathcal{G}\,\mathcal{F}\ GotoA_s\ \wedge\ \mathcal{G}\,\mathcal{F}\ GotoB_s\ \wedge\ \mathcal{G}\,\mathcal{F}\ GotoC_s$$

- **Run Information under MCTS with Verifier**:

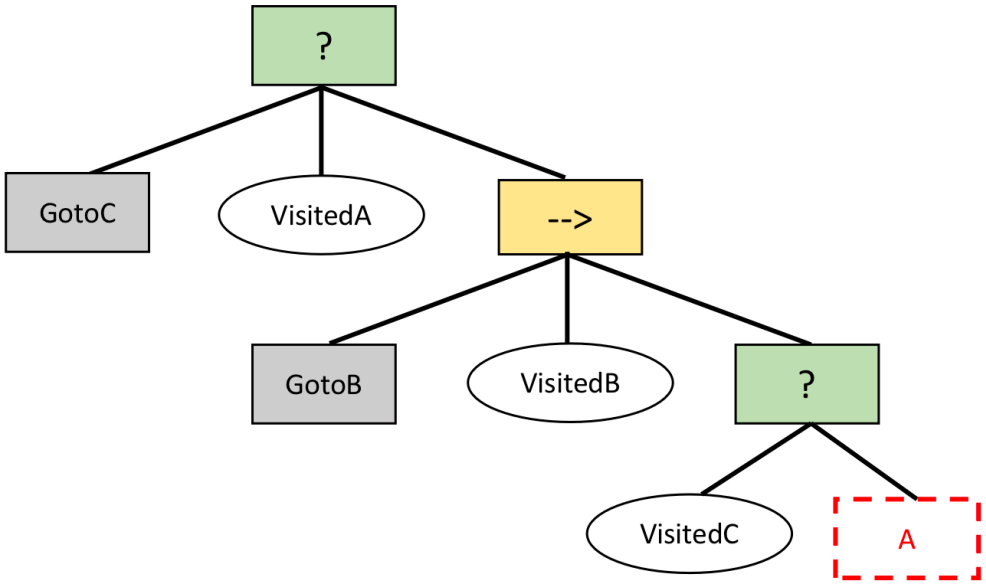
```
timecost:  123.77410221099854
verification time ratio:  1.3683 (169.36/123.77)
storing ratio:  0.9215 (327[Verify]+389[NoVerify]/777)
pruning ratio:  0.0785 (19[Com-V]+38[Incom-V]+4[Incom-S]/777)
pruning ratio in verification:  0.1484
```

- **Synthesized BT under MCTS with Verifier**:



MCTS with verifier

- **Synthesized BT under MCTS with Simulator (1 hour)**:



MCTS with simulator

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3. Mission_patrol$_2$

- **Mission Description**: The mission requires a robot to infinitely visit positions A, B, and C in order.
- **Available Nodes**:
  - $Action$: $GotoA$, $GotoB$, $GotoC$
  - $Condition$: $VisitedA$, $VisitedB$, $VisitedC$
- **Nodes' Function**:

Action	Requirement	Result
GotoA	\	VisitedA
GotoB	\	VisitedB
GotoC	\	VisitedC

- **Specification**:

$$\varphi = \mathcal{G}\,(\mathcal{F}\,(GotoA_s \ \wedge\ (\mathcal{F}\,(GotoB_s \ \wedge\ \mathcal{F}\ GotoC_s))))$$

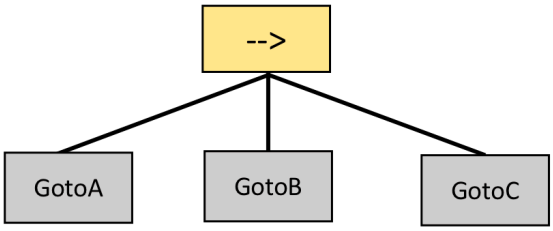
$$\wedge\,(\neg GotoB_s \ \wedge\ \neg GotoC_s)\ \mathcal{U}\ GotoA_s$$

$$\wedge\,\neg GotoC_s\ \mathcal{U}\ GotoB_s$$

- **Run Information under MCTS with Verifier**:

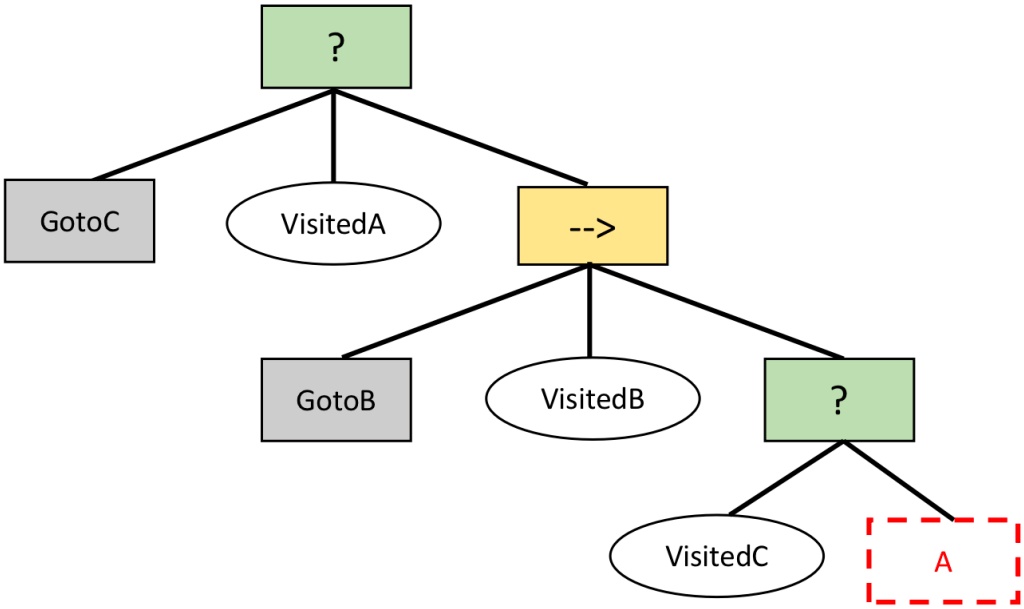
```
timecost:  182.22315382957458
verification time ratio:  1.3146 (239.55/182.22)
storing ratio:  0.914 (479[Verify]+563[NoVerify]/1140)
pruning ratio:  0.086 (23[Com-V]+55[Incom-V]+20[Incom-S]/1140)
pruning ratio in verification:  0.14
```

- **Synthesized BT under MCTS with Verifier**:



MCTS with verifier

- **Synthesized BT under MCTS with Simulator (1 hour)**:



MCTS with simulator

4. Mission_pickup

- **Mission Description**: The mission requires that a robot needs to navigate to the position A then pick up a cube from A, after that, navigate to the position B and place the cube on B.
- **Available Nodes**:
  - $Action$: $GotoA$, $GotoB$, $Pickup$, $Place$
  - $Condition$: AtA, AtB, $Picked$, $Placed$
- **Nodes' Function**:

Action	Requirement	Result
GotoA	\	AtA, ¬AtB
GotoB	\	¬AtA, AtB
Pickup	AtA, ¬Picked	Picked
Place	AtB, Picked	¬Picked, Placed

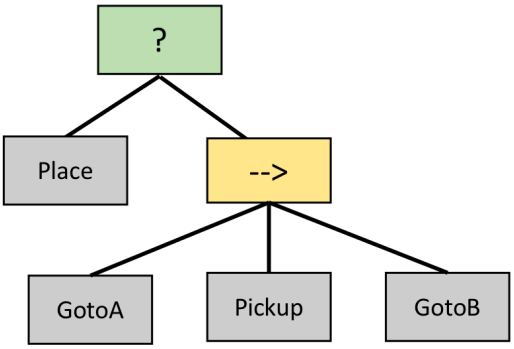
- **Specification**:

$$\varphi = \mathcal{F}\ Pickup_s \ \wedge\ \mathcal{F}\ Place_s$$

- **Run Information under MCTS with Verifier**:

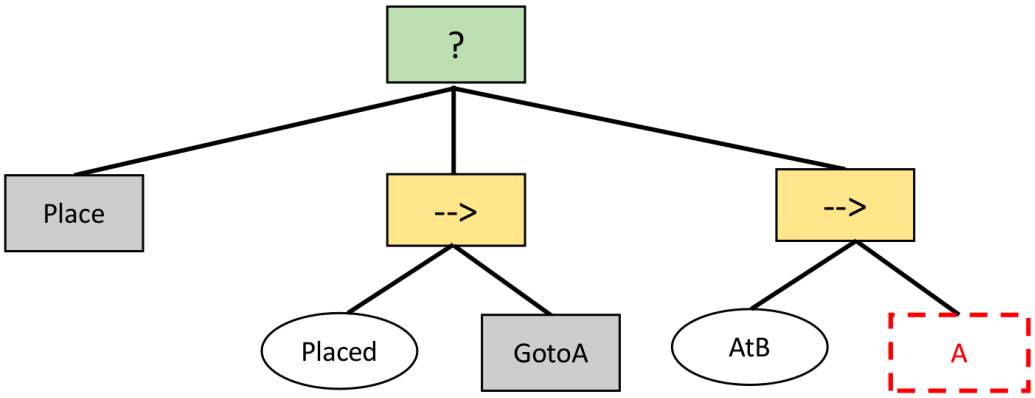
```
timecost:  1101.5370717048645
verification time ratio:  1.3345 (1469.99/1101.54)
storing ratio:  0.929 (3114[Verify]+3639[NoVerify]/7269)
pruning ratio:  0.071 (74[Com-V]+239[Incom-V]+203[Incom-S]/7269)
pruning ratio in verification:  0.0913
```

- **Synthesized BT under MCTS with Verifier**:



MCTS with verifier

- **Synthesized BT under MCTS with Simulator (1 hour)**:



MCTS with simulator

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5. Mission_alarm

- **Mission Description**: The mission contains an unexpected influence factor ***Alarm*** in the environment. The robot may navigate to the position A to complete TaskA if the alarm occurs or navigate to the position B to complete TaskB if the alarm doesn't occur.
- **Available Nodes**:
  - $Action: GotoA,\ GotoB,\ DoTaskA,\ DoTaskB$
  - $Condition: AtA,\ AtB,\ TaskACompleted,\ TaskBCompleted,\ Alarm$
- **Nodes' Function**:

Action	Requirement	Result
GotoA	\	AtA, ¬AtB
GotoB	\	¬AtA, AtB
DoTaskA	AtA, Alarm, ¬TaskACompleted	TaskACompleted
DoTaskB	AtB, ¬Alarm, ¬TaskBCompleted	TaskBCompleted

- **Specification**:

$$\varphi = \mathcal{F}\,(DoTaskA_s \ \vee \ DoTaskB_s)$$

$$\wedge\, \mathcal{F}\,(Alarm_s \ \vee \ Alarm_f)$$

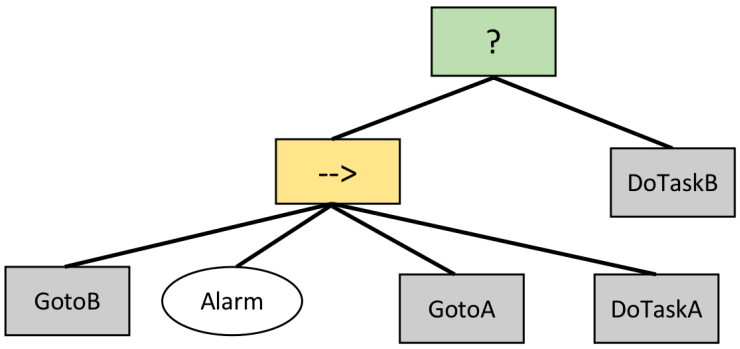
$$\wedge\, \mathcal{G}\,(Alarm_s \rightarrow (\,(\neg DoTaskB_s \ \mathcal{U}\ Alarm_f) \ \vee \ \mathcal{G}\,\neg DoTaskB_s\,)\,)$$

$$\wedge\, \mathcal{G}\,(Alarm_f \rightarrow (\,(\neg DoTaskA_s \ \mathcal{U}\ Alarm_s) \ \vee \ \mathcal{G}\,\neg DoTaskA_s\,)\,)$$

- **Run Information under MCTS with Verifier**:

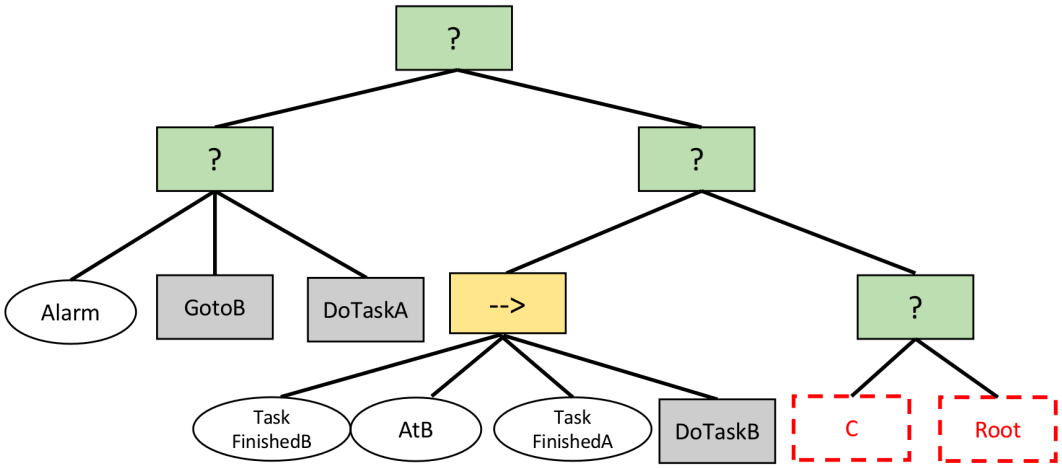
```
timecost:  2534.806505203247
verification time ratio:  1.2958 (3284.66/2534.81)
storing ratio:  0.9476 (6825[Verify]+7561[NoVerify]/15181)
pruning ratio:  0.0524 (116[Com-V]+237[Incom-V]+442[Incom-S]/15181)
pruning ratio in verification:  0.0492
```

- **Synthesized BT under MCTS with Verifier**:



MCTS with verifier

- **Synthesized BT under MCTS with Simulator (1 hour)**:



MCTS with simulator

Contacts

Please feel free to contact us if you have any problem.

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