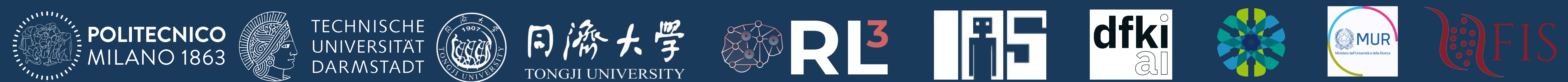
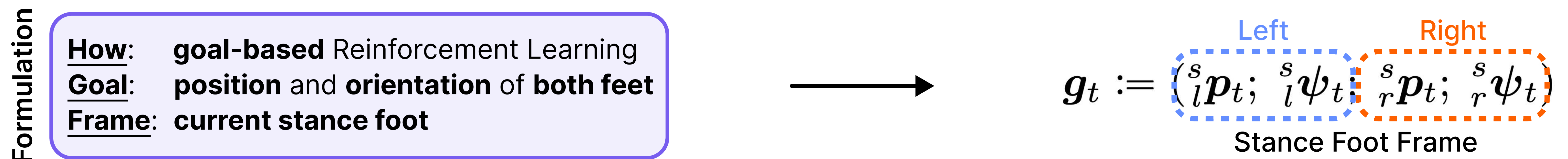


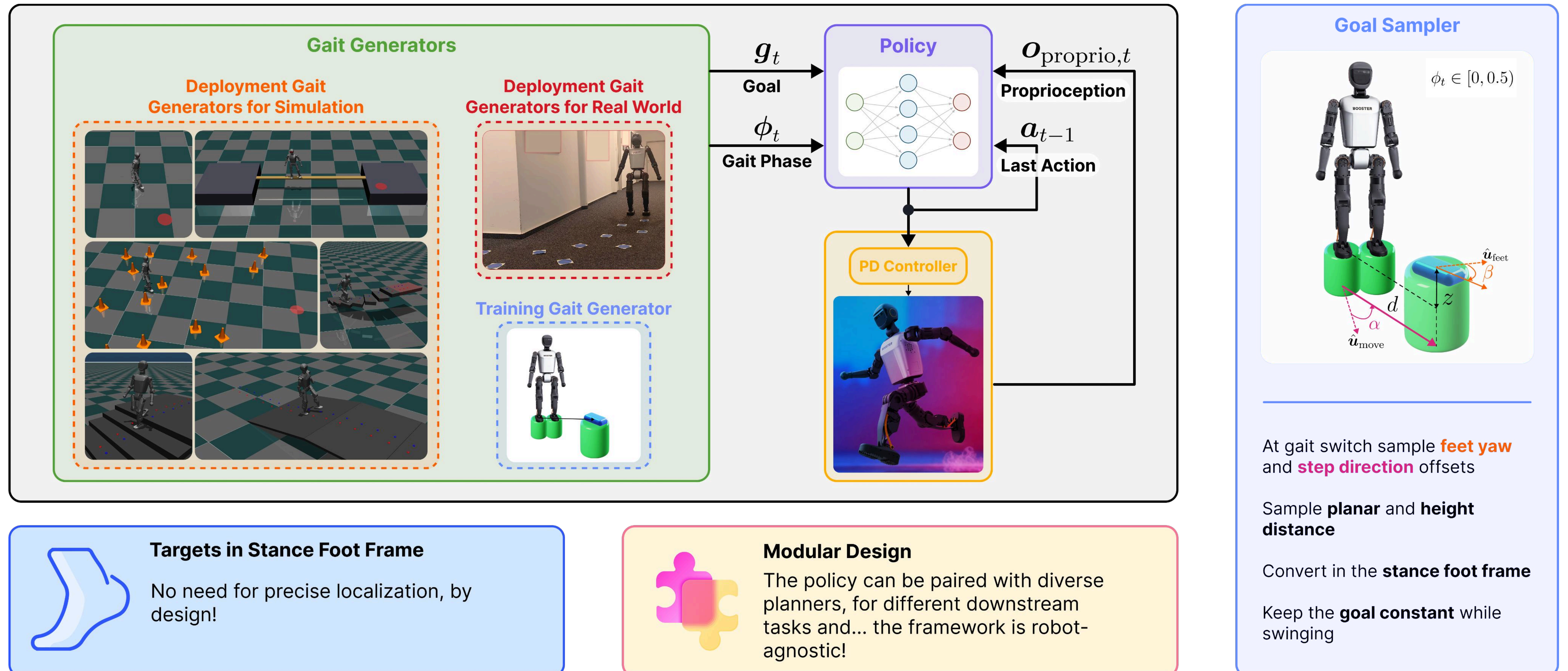
# Accurate Humanoid Locomotion: Ditch Velocity Commands, Track Footholds.



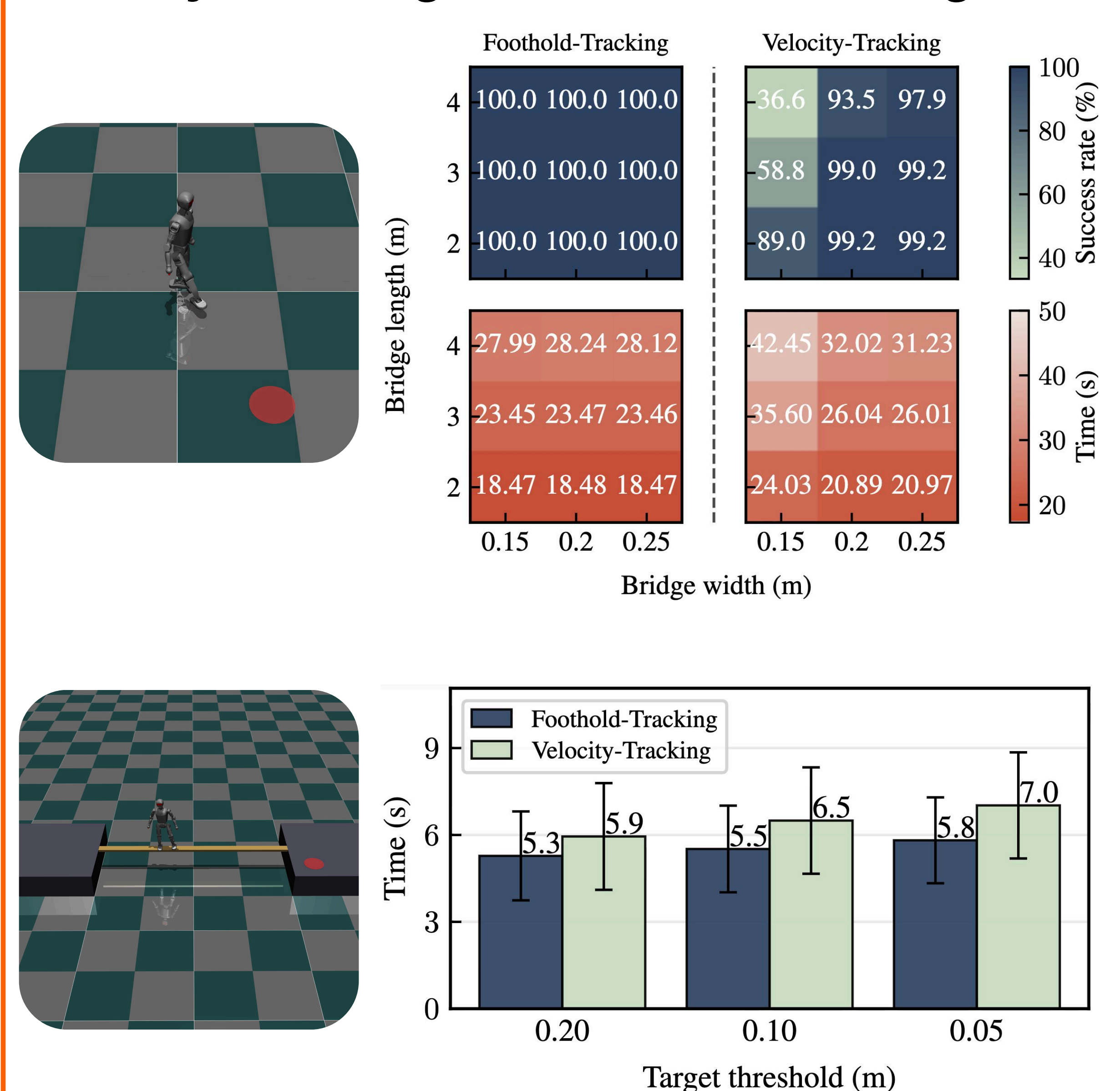
## Mind Your Steps: A General Learning Framework for Accurate Humanoid Foothold Tracking



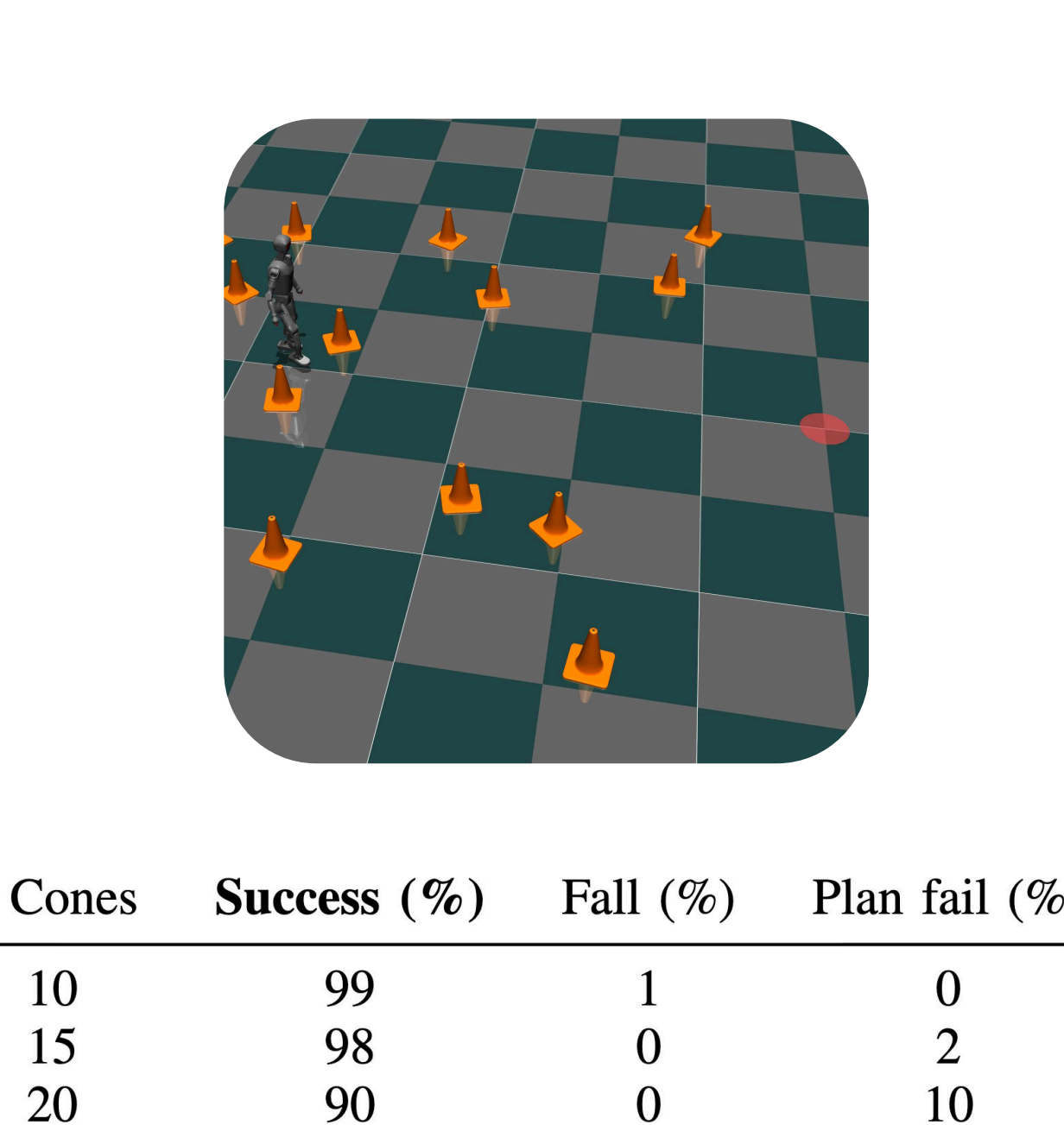
### Framework and Architecture



### Velocity-Tracking vs. Foothold-Tracking



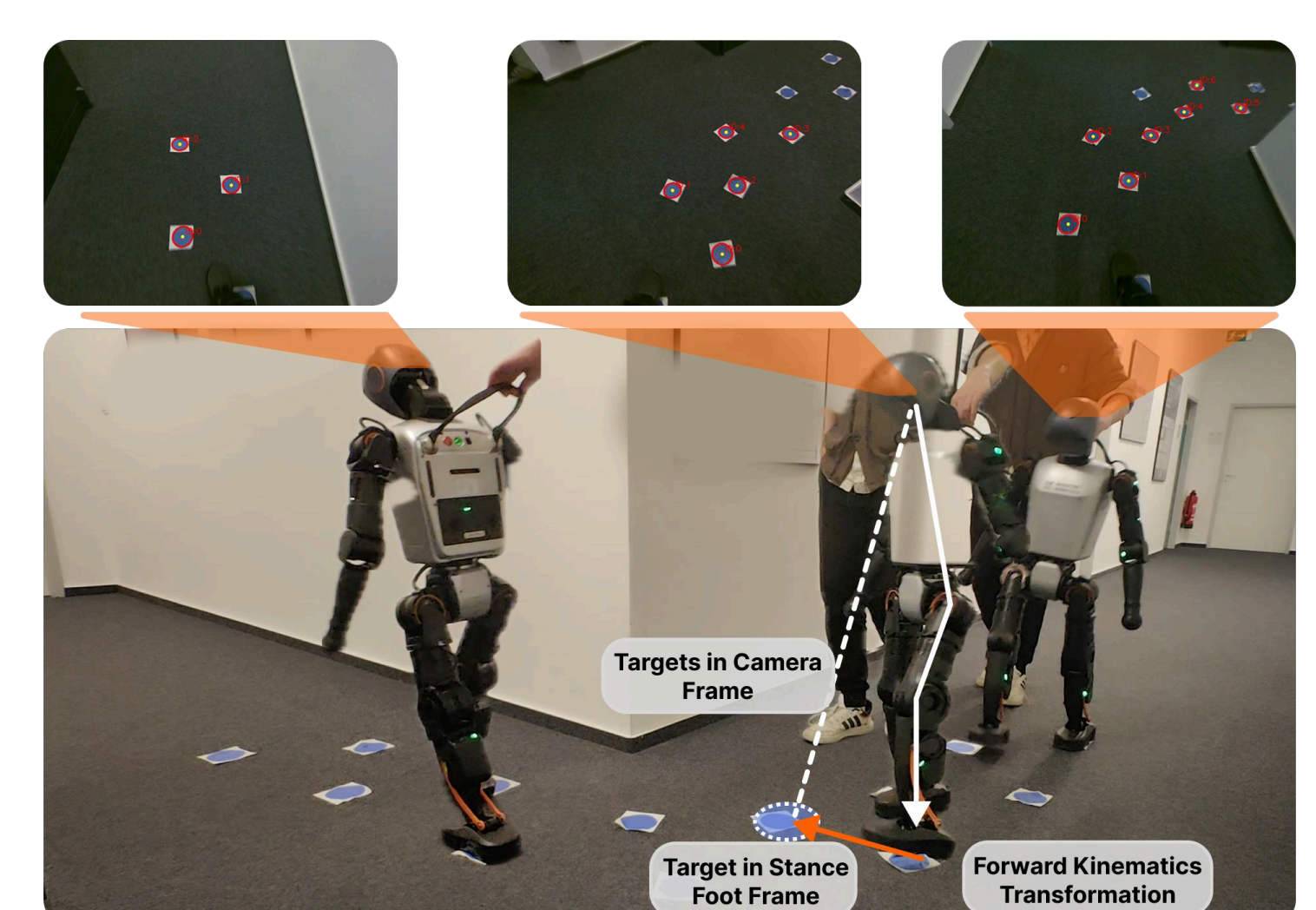
### Cluttered Environment



### Unitree G1: Harsh Terrains



### Booster T1: Flat Terrains



### Stairs Traversal

| Step Length (m) | Step Height (m)                |                                |                                |                                 |                                |                                 |                                 |
|-----------------|--------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|---------------------------------|
|                 | 0.08                           | 0.10                           | 0.11                           | 0.115                           | 0.12                           | 0.125                           | 0.13                            |
| 0.300           | 95%<br>R:3 B:2<br>0.059±0.089  | 76%<br>R:19 B:5<br>0.071±0.049 | 60%<br>R:40 B:0<br>0.081±0.048 | 52%<br>R:34 B:14<br>0.090±0.048 | 56%<br>R:39 B:5<br>0.083±0.041 | 38%<br>R:47 B:15<br>0.095±0.038 | 12%<br>R:70 B:18<br>0.108±0.039 |
| 0.325           | 100%<br>R:0 B:0<br>0.038±0.005 | 100%<br>R:0 B:0<br>0.041±0.006 | 92%<br>R:5 B:3<br>0.050±0.029  | 89%<br>R:11 B:0<br>0.053±0.027  | 74%<br>R:22 B:4<br>0.068±0.042 | 30%<br>R:54 B:16<br>0.104±0.045 | 6%<br>R:80 B:14<br>0.115±0.038  |
| 0.350           | 100%<br>R:0 B:0<br>0.040±0.005 | 99%<br>R:1 B:0<br>0.045±0.022  | 100%<br>R:0 B:0<br>0.045±0.016 | 96%<br>R:2 B:2<br>0.050±0.022   | 89%<br>R:7 B:4<br>0.066±0.056  | 47%<br>R:34 B:19<br>0.106±0.060 | 19%<br>R:58 B:23<br>0.136±0.057 |
| 0.375           | 100%<br>R:0 B:0<br>0.048±0.011 | 100%<br>R:0 B:0<br>0.052±0.010 | 99%<br>R:0 B:1<br>0.054±0.017  | 86%<br>R:4 B:10<br>0.058±0.019  | 88%<br>R:8 B:4<br>0.079±0.100  | 87%<br>R:6 B:7<br>0.087±0.112   | 46%<br>R:23 B:31<br>0.113±0.086 |

### Spiral Traversal

| Step Length (m) | Step Height (m)               |                                |                                 |                                 |                                 |                                 |                                 |
|-----------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                 | 0.08                          | 0.10                           | 0.11                            | 0.115                           | 0.12                            | 0.125                           | 0.13                            |
| 0.300           | 97%<br>R:2 B:1<br>0.045±0.017 | 82%<br>R:17 B:1<br>0.061±0.029 | 40%<br>R:40 B:20<br>0.082±0.028 | 21%<br>R:61 B:18<br>0.104±0.031 | 14%<br>R:71 B:15<br>0.114±0.034 | 19%<br>R:73 B:8<br>0.112±0.030  | 14%<br>R:72 B:14<br>0.132±0.053 |
| 0.325           | 97%<br>R:2 B:1<br>0.049±0.044 | 91%<br>R:3 B:6<br>0.060±0.025  | 77%<br>R:15 B:8<br>0.066±0.035  | 58%<br>R:20 B:22<br>0.085±0.040 | 66%<br>R:31 B:3<br>0.082±0.050  | 29%<br>R:59 B:12<br>0.097±0.038 | 17%<br>R:62 B:21<br>0.104±0.031 |
| 0.350           | 96%<br>R:0 B:4<br>0.061±0.068 | 94%<br>R:4 B:2<br>0.065±0.088  | 91%<br>R:3 B:6<br>0.074±0.098   | 84%<br>R:8 B:8<br>0.084±0.095   | 79%<br>R:13 B:8<br>0.093±0.107  | 57%<br>R:25 B:18<br>0.097±0.059 | 28%<br>R:55 B:17<br>0.132±0.061 |
| 0.375           | 91%<br>R:4 B:5<br>0.081±0.038 | 90%<br>R:4 B:6<br>0.090±0.137  | 96%<br>R:1 B:3<br>0.069±0.048   | 93%<br>R:1 B:6<br>0.089±0.126   | 74%<br>R:7 B:19<br>0.097±0.067  | 54%<br>R:16 B:30<br>0.125±0.107 | 17%<br>R:45 B:37<br>0.155±0.097 |