

# Learning Surfing-like Balance **without Water Simulation**

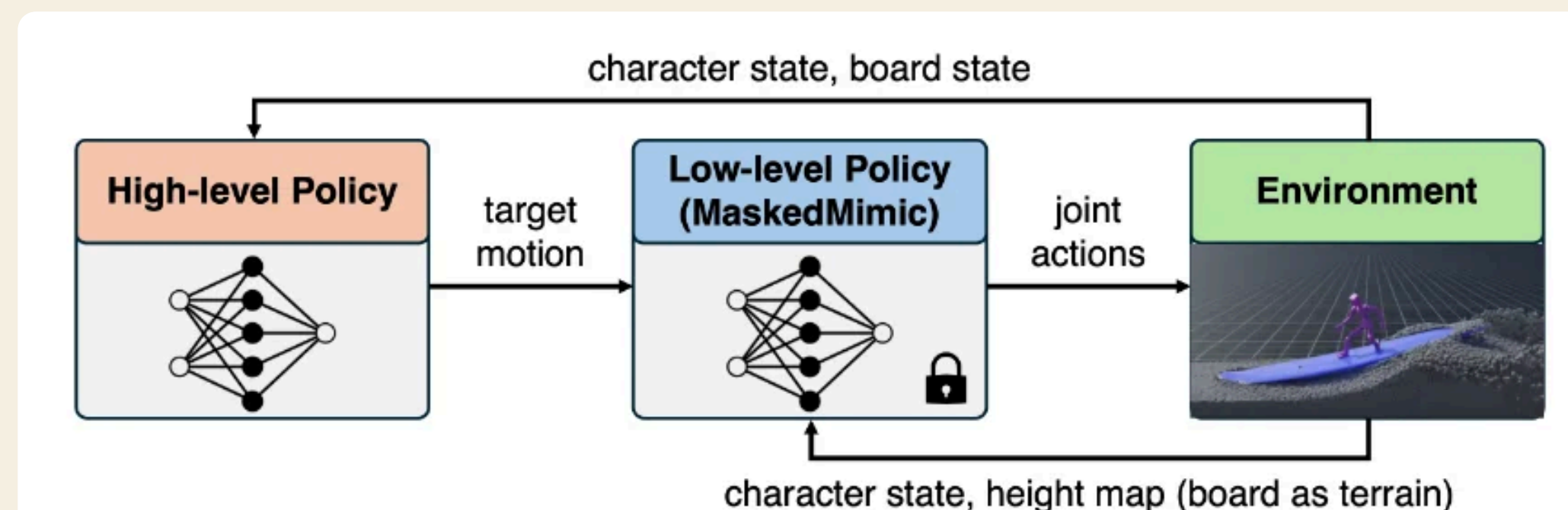
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## 01 OVERVIEW

Surfing means balancing on a continuously moving board, yet simulating water is costly and unstable. We learn surfing-like balance entirely without water simulation — through a hierarchical controller and a stage-based curriculum that progressively introduces dynamic board behavior.

### Hierarchical control framework



## 02 METHOD

### STAGE 1

#### Balance on board

The board is suspended in air with a restoring torque on its **pitch** and no roll stabilization. The policy learns to compensate for lateral instability while the board stays level forward.

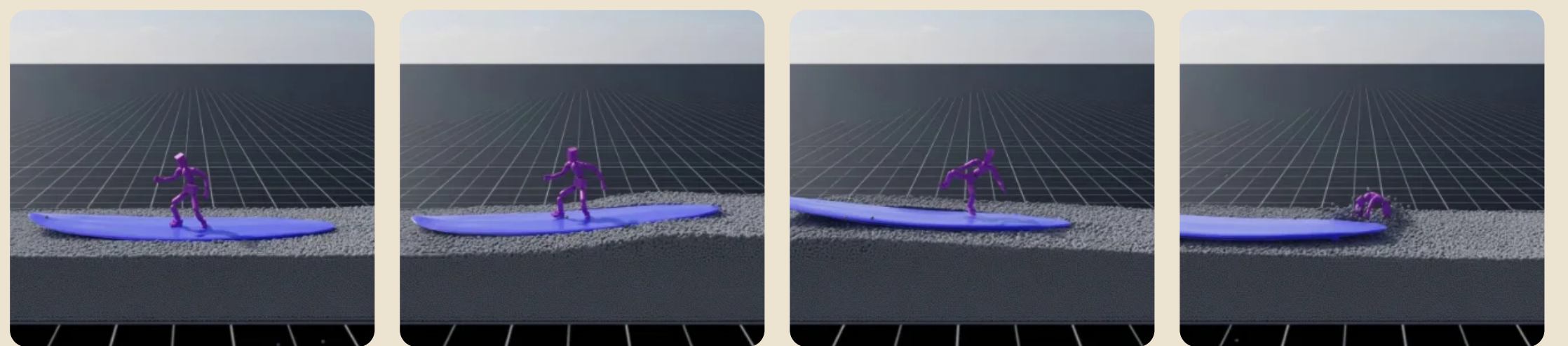
### STAGE 2

#### Balance with forward motion

Building on Stage 1, the board **moves forward** while its target pitch tilts from horizontal to forward-leaning, resembling real surfing conditions.

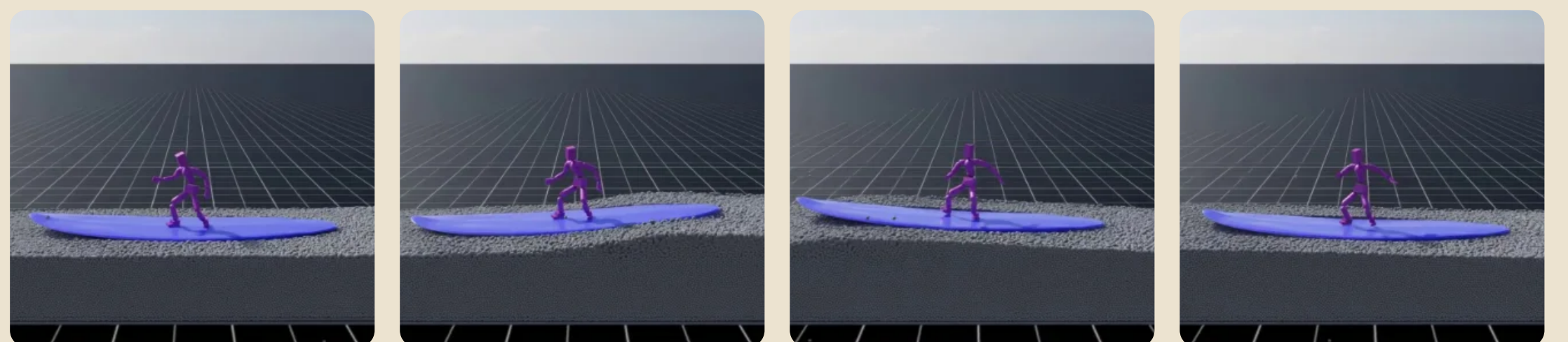
### × STAGE 1 ONLY

ablation — without Stage 2, the character **loses balance and falls**

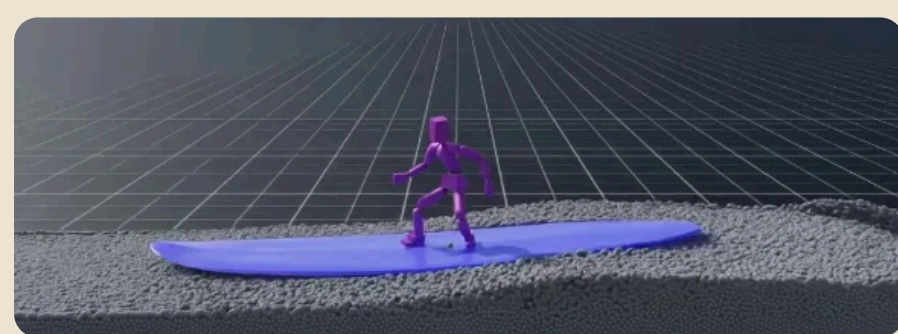


### ✓ OURS · STAGE 1 → 2

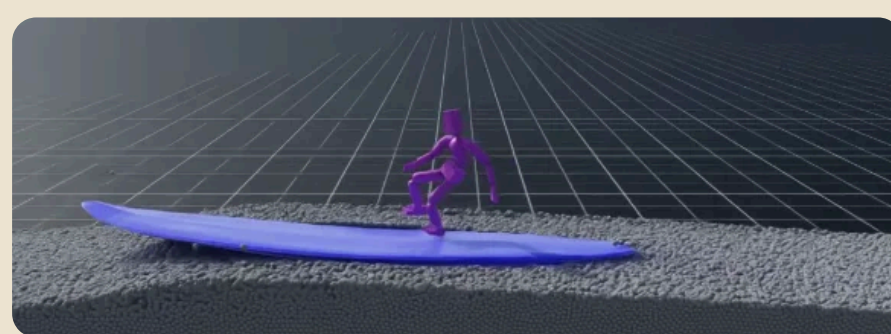
full curriculum — the character **stays balanced and surfs**



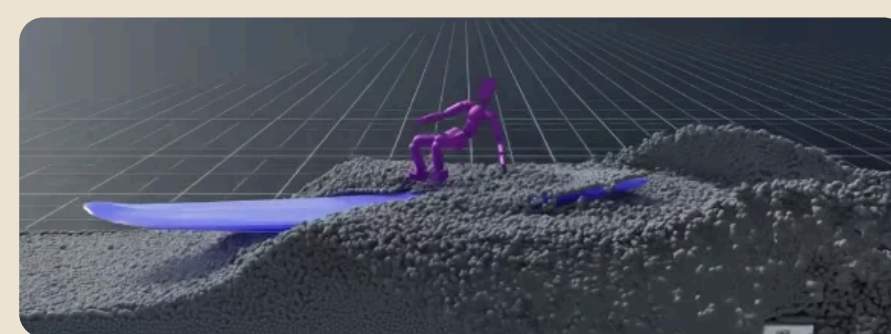
## 03 RESULTS — DIFFERENT WAVE CONDITIONS



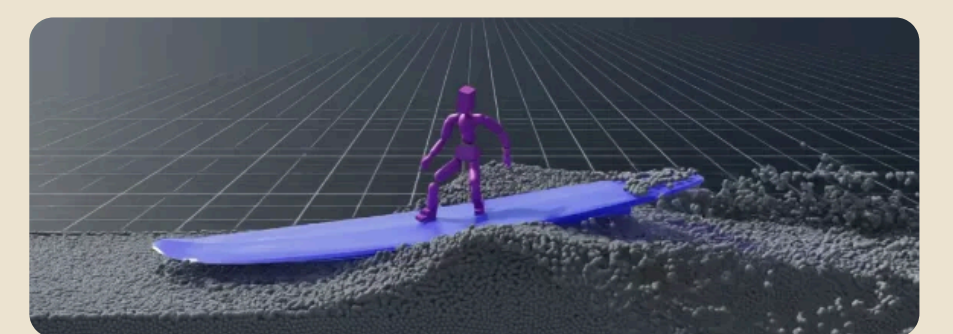
Low wave



Medium wave



High wave



Fast wave

Although trained **entirely without water**, the learned policy keeps balance on a moving board across wave heights and speeds at runtime — and often **recovers** from disturbances. Stage-based training is the key driver of robustness.

Stage 1 only → Stage 1 + 2

#### SUCCESS RATE

15% → **60%**

#### AVG. SURVIVAL STEPS

198 → **283** steps

1 step = 1/30 s (350-step episode limit)

#### Video & Project



Scan for the  
supplementary  
video and full results