

# World models

Predict what happens next, before you act.



$\hat{s}_{t+1} = f(s_t, a_t)$   
chain it → a rollout  
compare → the error

FAMILY 1

## Physics-based

Equations written by experts.  
MuJoCo · EnergyPlus · Modelica · SUMO  
+ accurate, explainable, needs little data  
– slow, laborious to set up and calibrate

FAMILY 2

## Learned

A neural network trained on data to predict the next state.  
Dreamer · MuZero · video world models (Genie, Cosmos)  
+ fast; learns what is hard to write down  
– confidently wrong outside its training data

FAMILY 3

## Hybrid

Physics where it is known, learning where it is not.  
physics-informed nets · surrogates of simulators · grey-box  
+ data-efficient, easier to trust  
– harder to design and to train

## How it is used

- Planning** — try candidate actions in the model, pick the best
- Model predictive control** — optimise over a horizon, apply the first step, repeat (common for HVAC)
- Model-based RL** — train the policy in imagination, not on the real system
- What-if analysis** — compare scenarios before building them
- Anomaly detection** — a large prediction error means something unexpected

## Vocabulary

|              |                                                |
|--------------|------------------------------------------------|
| State        | what the world is like now                     |
| Action       | what the agent changes                         |
| Dynamics     | the rule: state + action → next state          |
| Observation  | what sensors see; often only part of the state |
| Rollout      | predictions chained forward in time            |
| Horizon      | how far ahead you predict                      |
| Latent state | a compressed state a network learns            |
| Surrogate    | a fast learned copy of a slow simulator        |

## Pitfalls

- Compounding error** — small errors grow over long rollouts
- Out of distribution** — trust drops outside the data it saw
- Sim-to-real gap** — the model is not the world; calibrate with measurements
- Garbage in** — wrong geometry or inputs give wrong predictions
- Exploited errors** — an optimiser finds the model's mistakes and uses them

## In the built environment

BUILDING ENERGY  
EnergyPlus, Modelica

MICROCLIMATE  
ENVI-met

CONTROL TESTING  
BOPTEST benchmarks

TRAFFIC  
SUMO

City model = **state**. Digital twin = state + world model.

URBAN ENERGY  
CitySim, UMI  
  
SUN AND SHADOW  
straight from CityGML geometry

## Landmarks to read

- 2018 Ha & Schmidhuber — World Models
- 2019 Raissi et al. — physics-informed neural networks
- 2020 Sanchez-Gonzalez et al. — Learning to Simulate
- 2020 Schrittwieser et al. — MuZero
- 2019–23 Hafner et al. — Dreamer, V1 to V3