Qualitatively Guided Training of Skills

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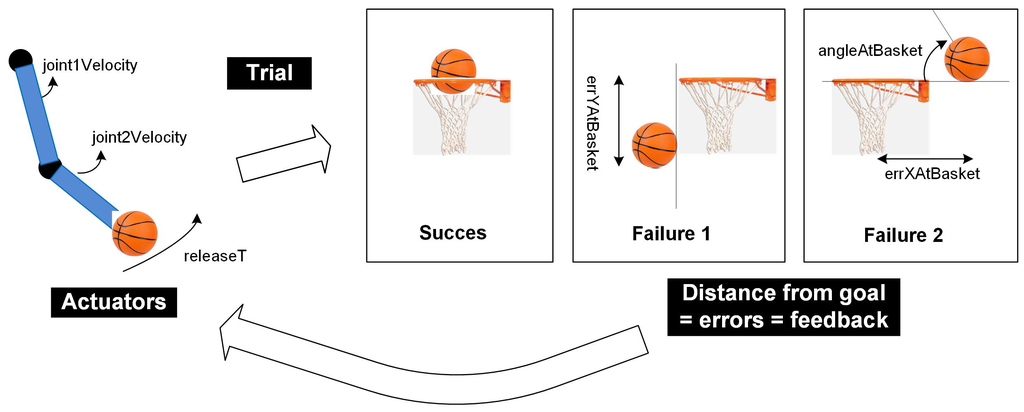
Training of a Skill: basketball



How to effectively adjust action parameters?

Simulation in 2D
Random first try

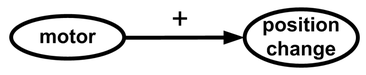
- **Reinforcement learning**: random tries
  => requires around 100,000 samples
- **Stochastic gradient descent**: ±200 tries
- **Our approach**: 5-15 trials

Qualitative Causal Models

Qaulitatively describing $s_{t+1} = f(s_t, a)$

Assumptions:
- qualitative determinism
- effective state variables
- known state

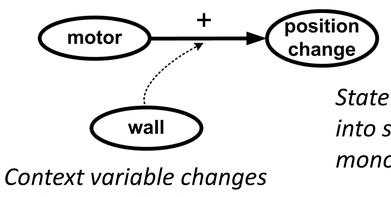
Monotone relationships



Also sign of derivatives:

$$\frac{\delta \text{position change}}{\delta \text{motor}} > 0$$

Subspaces



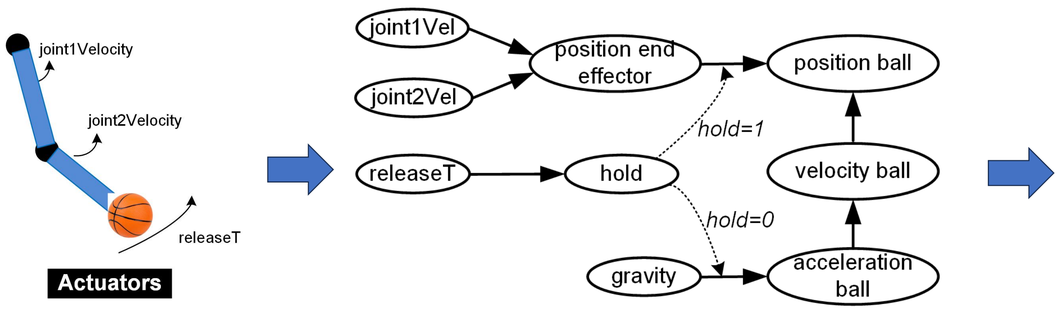
Context variable changes the causal behavior

State space is partitioned into subspaces with monotone behavior

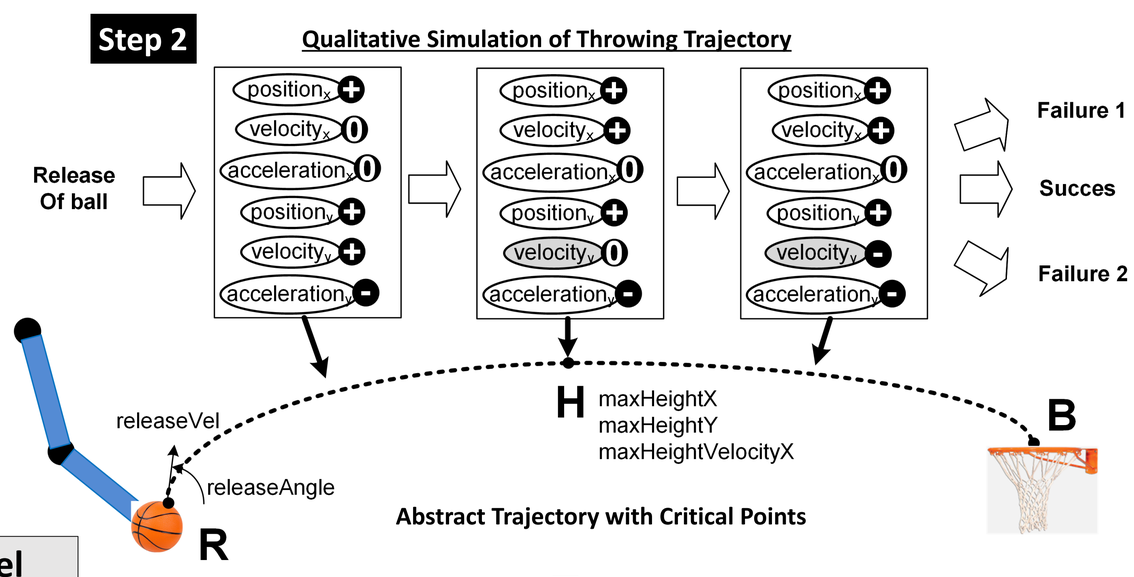
Like human learning

Hypothesis of how humans learn skills:
- qualitative reasoning happens consciously,
- quantitative tuning happens subconsciously.

Step 1 — Learning Qualitative Causal Model of Throwing



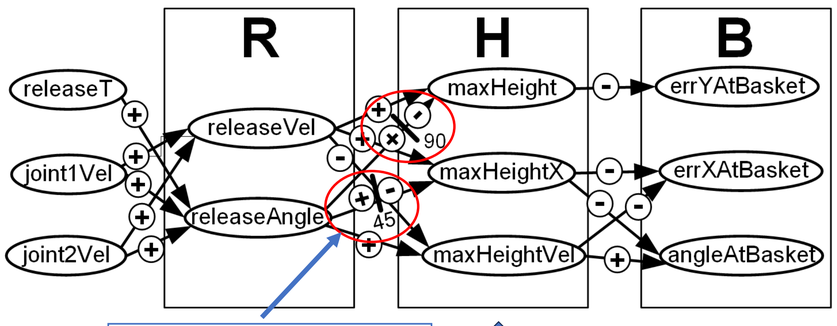
Step 2 — Qualitative Simulation of Throwing Trajectory



Abstract Trajectory with Critical Points

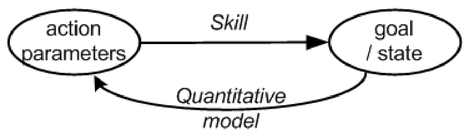
Based on the state variables at each critical point, a layered causal model is defined.

Step 3 — Learning Qualitative Causal Model of Changes to Variables



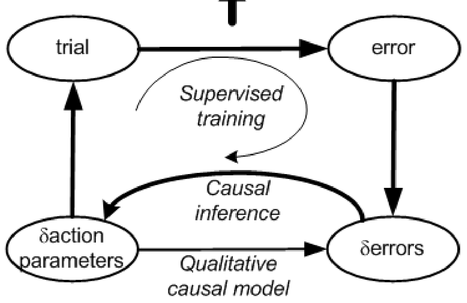
Contextual relationships

Step 5 — Successful throws allow the training of a quantitative model.



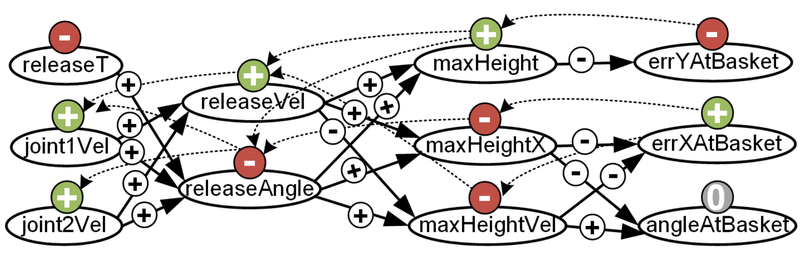
Qualitative model provides the effective tuning of the action parameters

Step 4 — Training



Action parameters are adjusted in a control loop. The sign of the changes is given by causal inference.

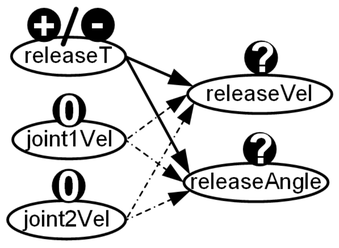
Causal inference on Qualitative model



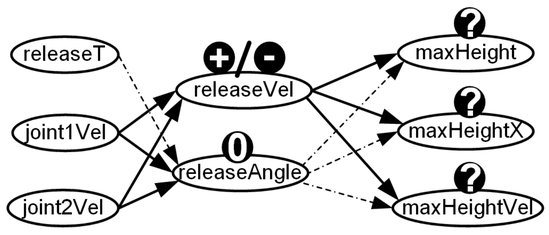
To infer the required changes to the actuations to reduce the errors, **backpropagate the sign of the errors**.
Multiple solutions are possible.

Incremental Model Learning with Hierarchical Skills

Level 1 Skill 1: Throwing a ball

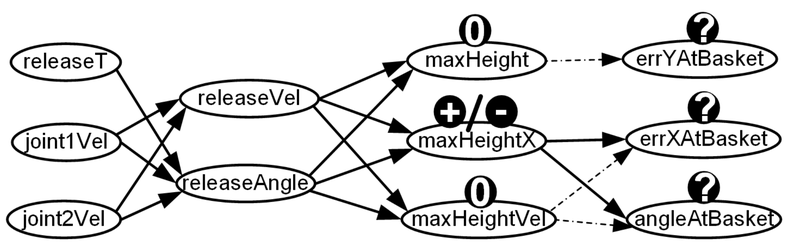


Level 2 Skill 2: Throwing a ball to a certain height



- Consecutively change one variable of the second layer by using a control loop and the causal inference applied to the model of level 1
- Observe effects in the third layer to identify qualitative relationship

Level 3 Skill 3: Throwing a ball into a basket



Use the model of level 2 to control the variables of the 3rd layer

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