Symposium on Explainability

WhiteBox · LOEWE Exzellente Forschung für Hessens Zukunft · Centre for Cognitive Science · TECHNISCHE UNIVERSITÄT DARMSTADT

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Closing the Loop in Robot Juggling

Juggling tasks provide excellent opportunities to study how humans coordinate their movements and learn new skills as well as to evaluate robot control approaches in dynamic and underactuated scenarios of variable complexity.


To investigate the utilization of feedback loops in this dynamic motor skill, we conducted experiments manipulating the quality of feedback in extreme scenarios of no feedback at all and perfect observations of the system state.
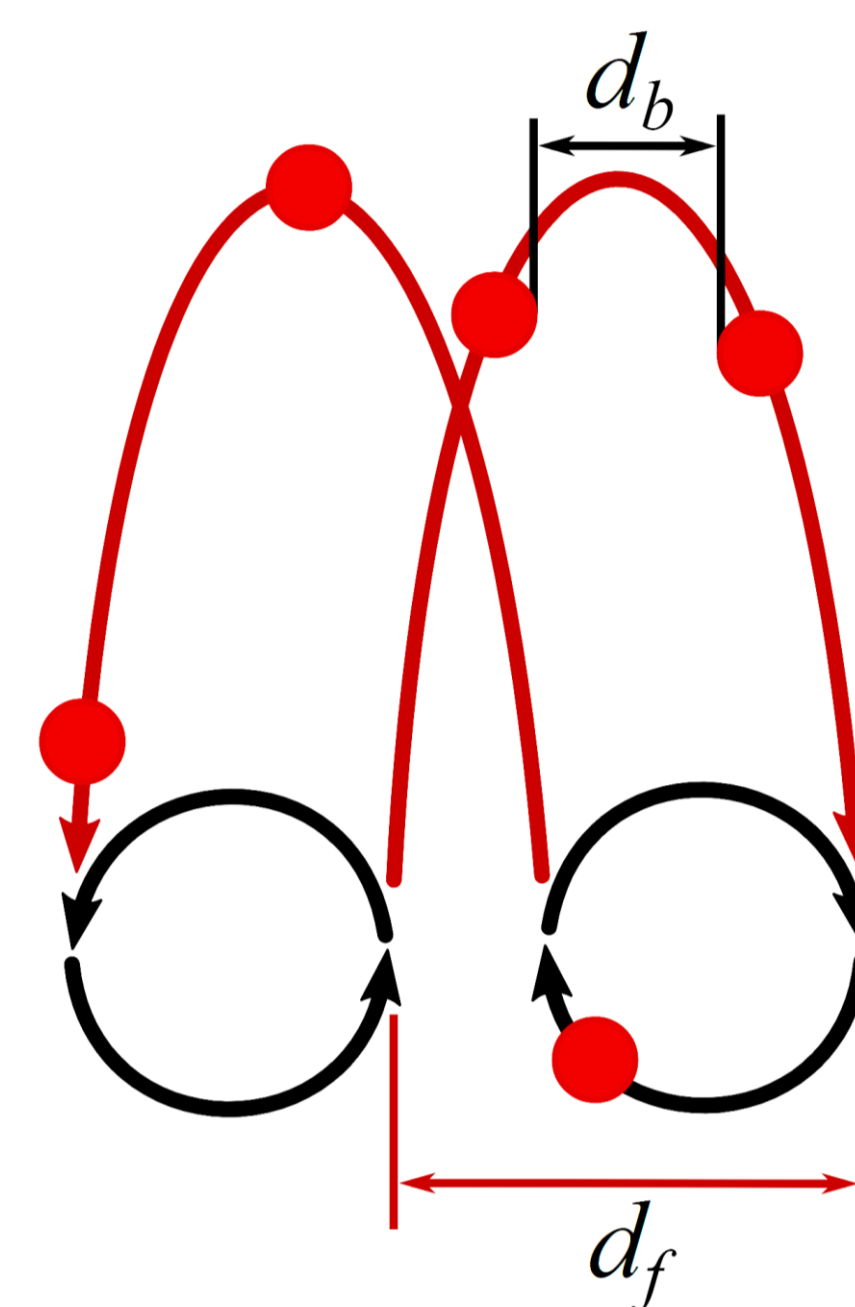
Learning to Juggle Blindfolded
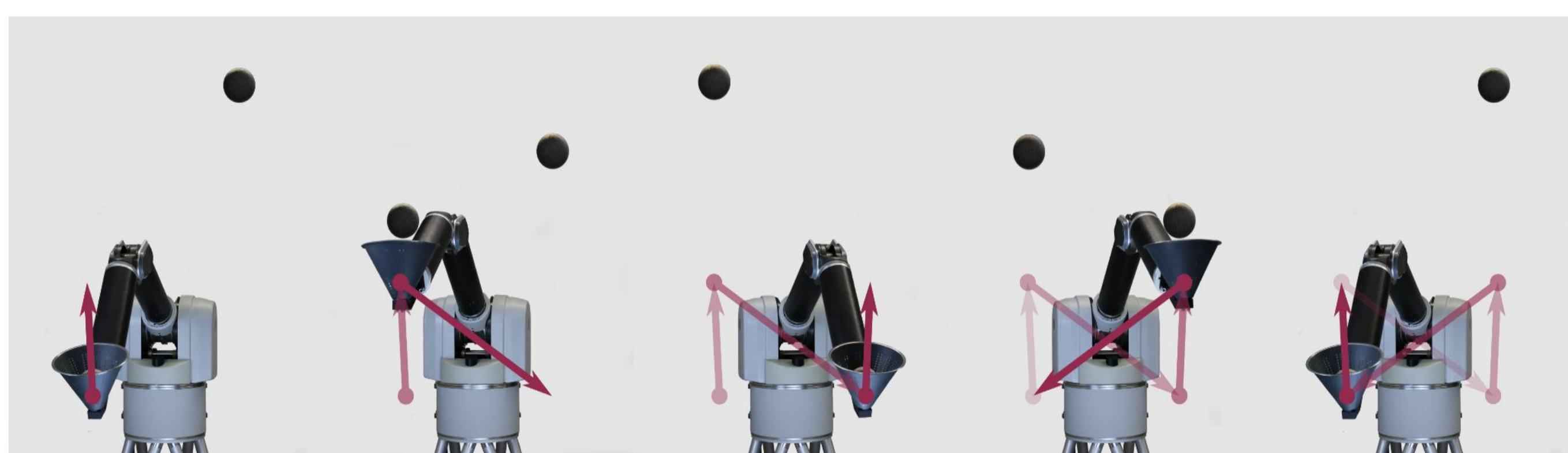
- Two balls in one hand
- No sensory feedback
- 56 min / 500 tries of learning experience
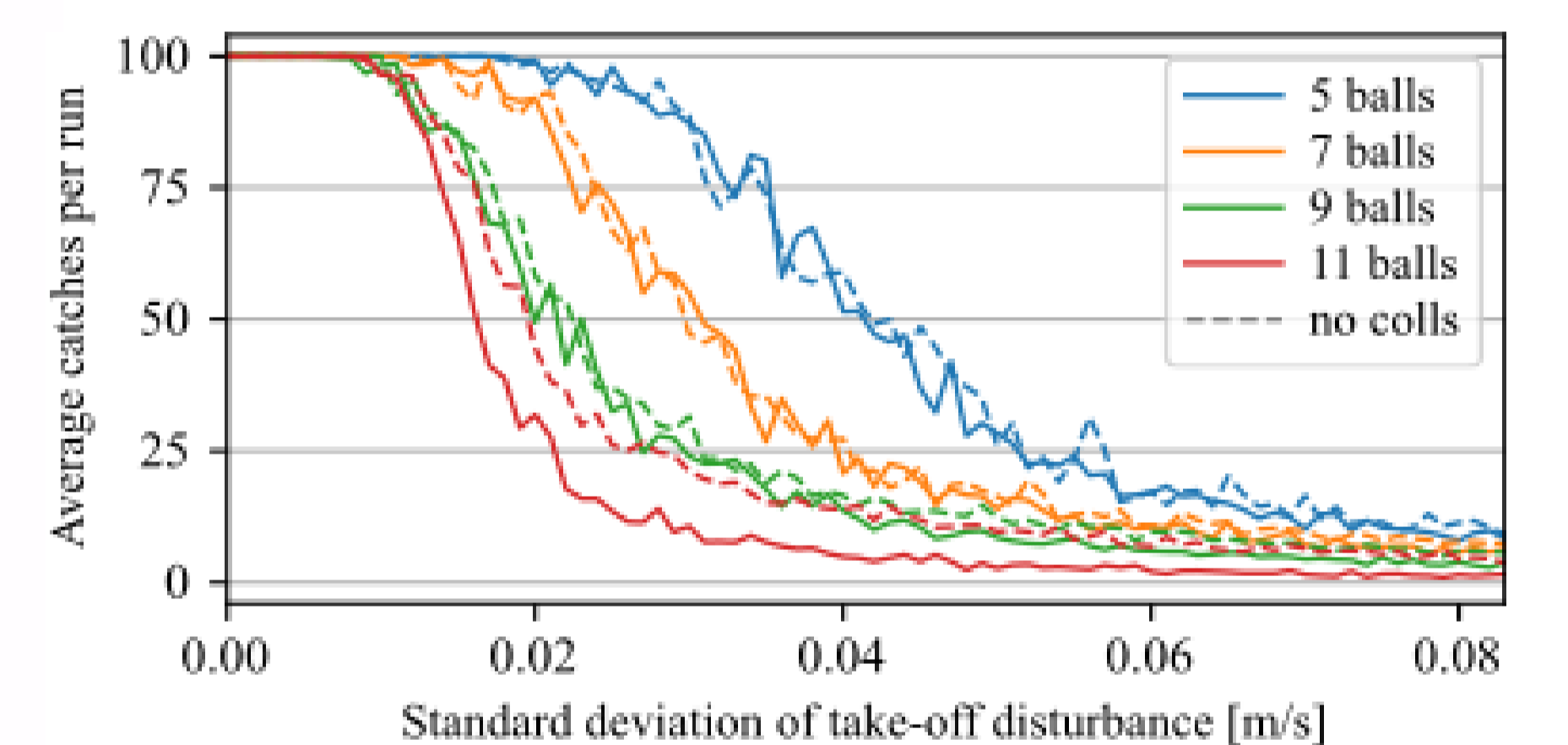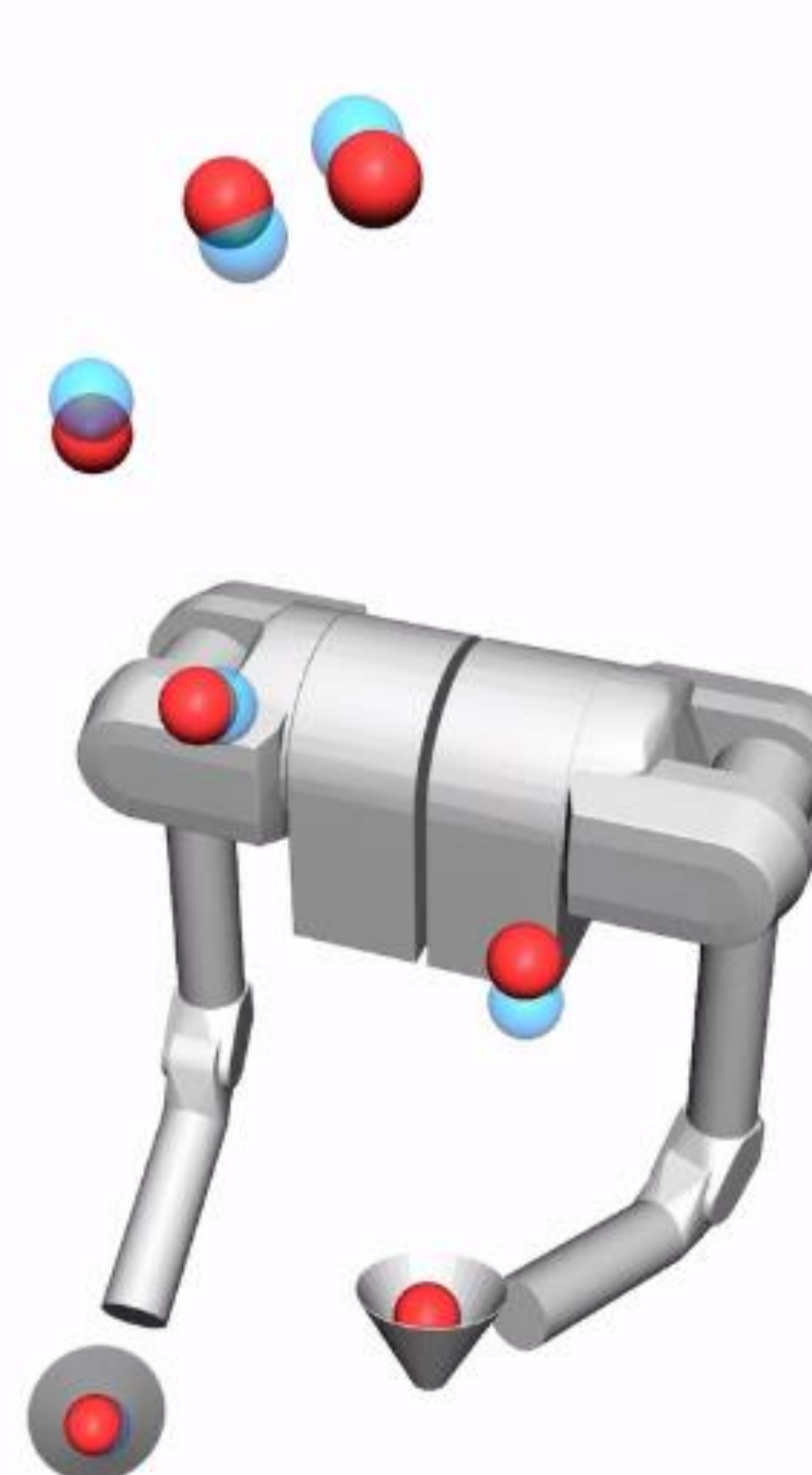- Continuous juggling for 33 min / 4500 catches
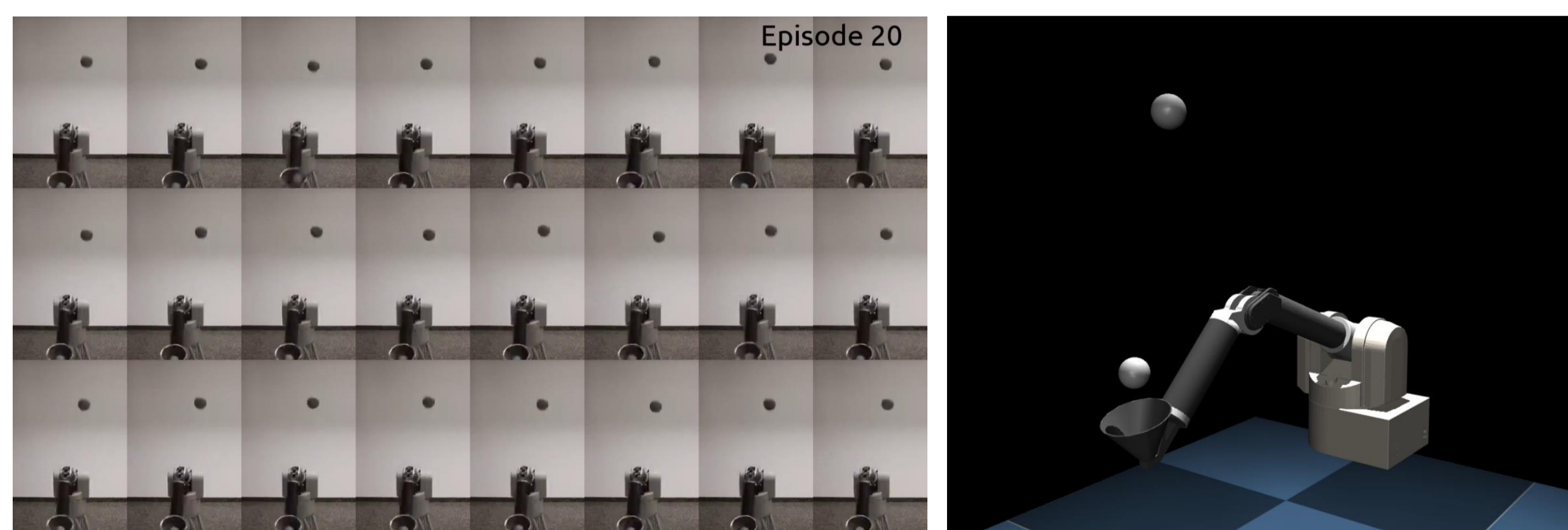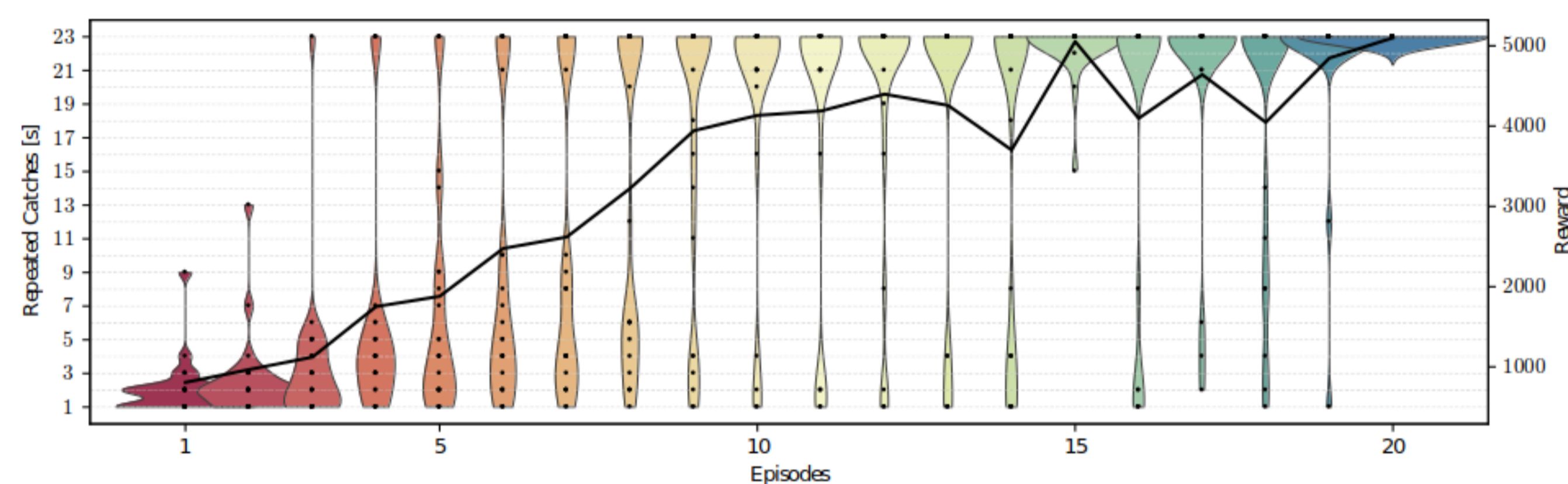
The Cascade Pattern

- Most common pattern
- Odd numbers of balls only
- Alternating crossing throws
- Maximum number of balls N_b restricted by d_b > 0
- World record: N_b = 13

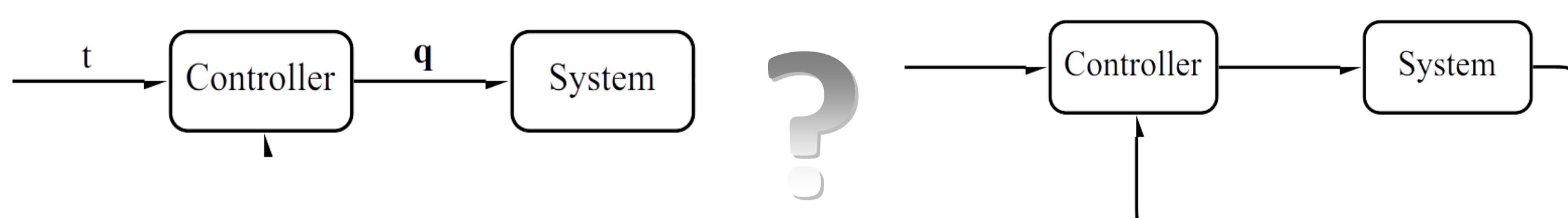$$N_b \leq \left\lfloor \frac{d_f}{r_b} + 2R \right\rfloor$$
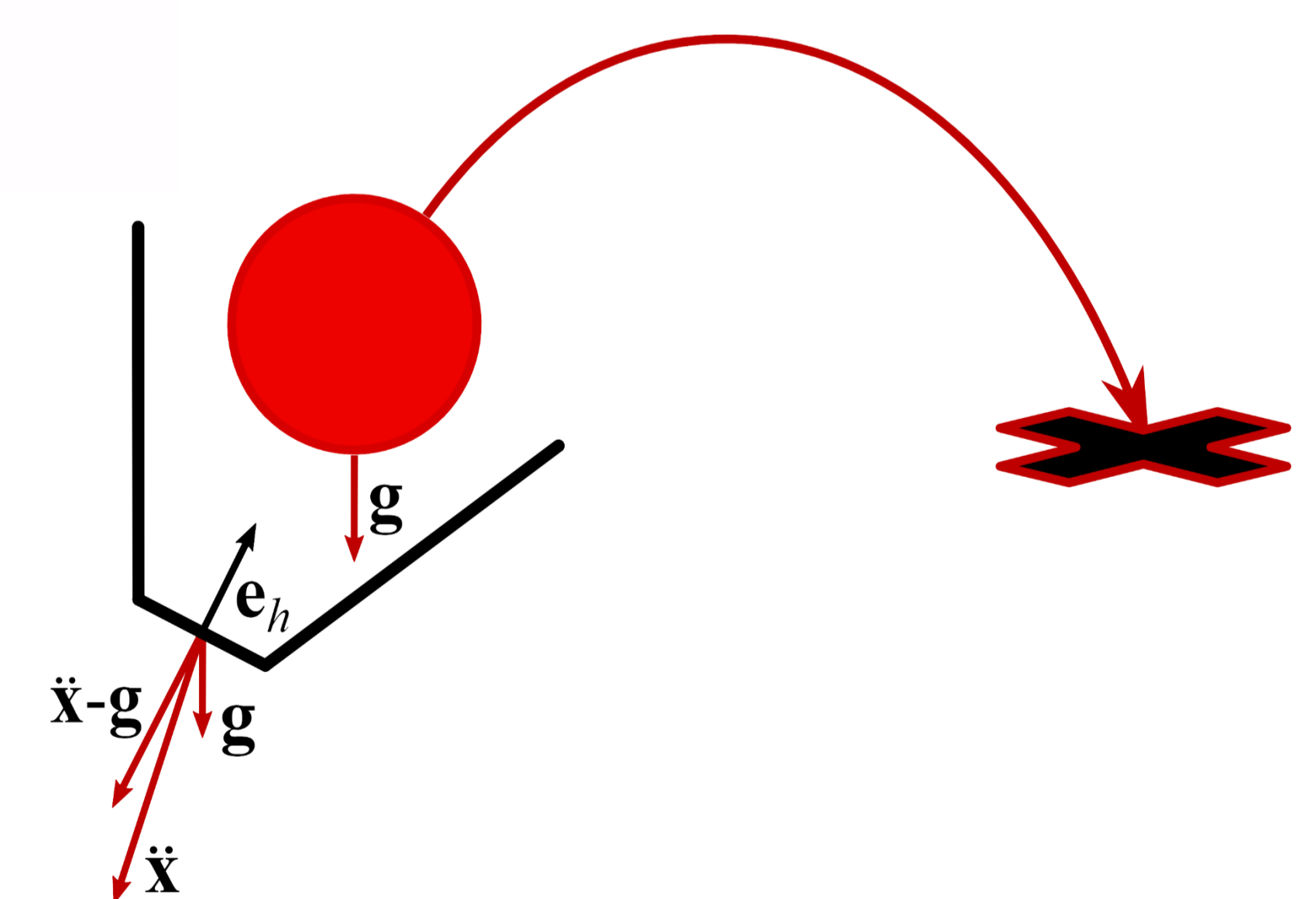
Closing the Loop in Robot Juggling

- MPC-style replanning
- 3-17 balls
- Reaching theoretic max balls
- Robust against disturbances

- Detailed analysis of the toss juggling task, identifying the key challenges of the switching contacts task and formalizing it as a trajectory optimization problem.

Open Loop vs Closed Loop

- Solved the problem open loop and closed loop
- Open loop is simple and quick to learn, but not robust to large disturbances
- Closed loop is robust to large disturbances, but relies heavily on quality sensors and compute

- How much feedback and compute do we need?
- Can we get inspiration from human motor control to find an efficient and resiliant controller?