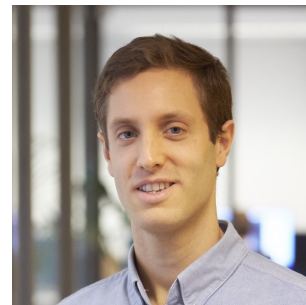# Causal Representation Learning for Instantaneous and Temporal Effects in Interactive Systems

Phillip Lippe, Sara Magliacane, Sindy Löwe, Yuki M. Asano, Taco Cohen, Efstratios Gavves

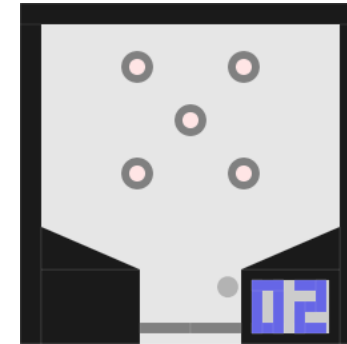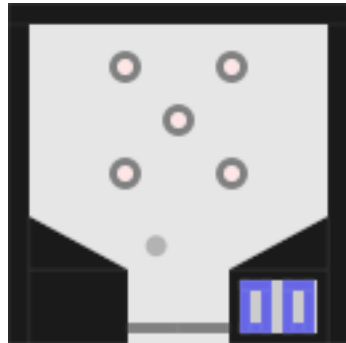# Causal Representation Learning

- Given high-dimensional observations of a dynamical system, what are the true causal variables?

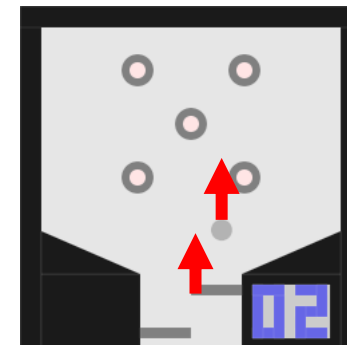- Crucial for reasoning, planning, generalization, and more
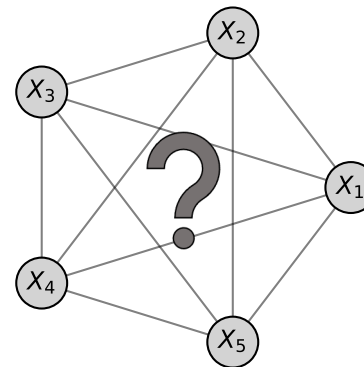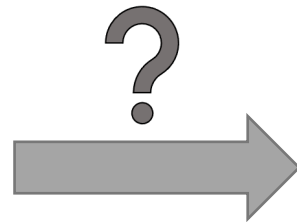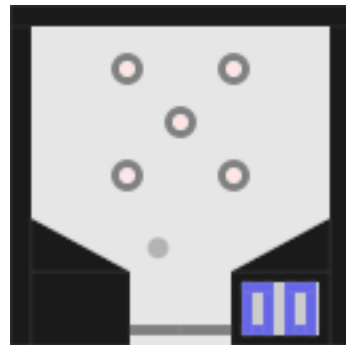
Instantaneous Effects in Temporal Sequences

- Common assumption: time resolves causal effects

- But what about observations at low frame rates?

⇒ Instantaneous Effects!

time step t

time step $t + 1$
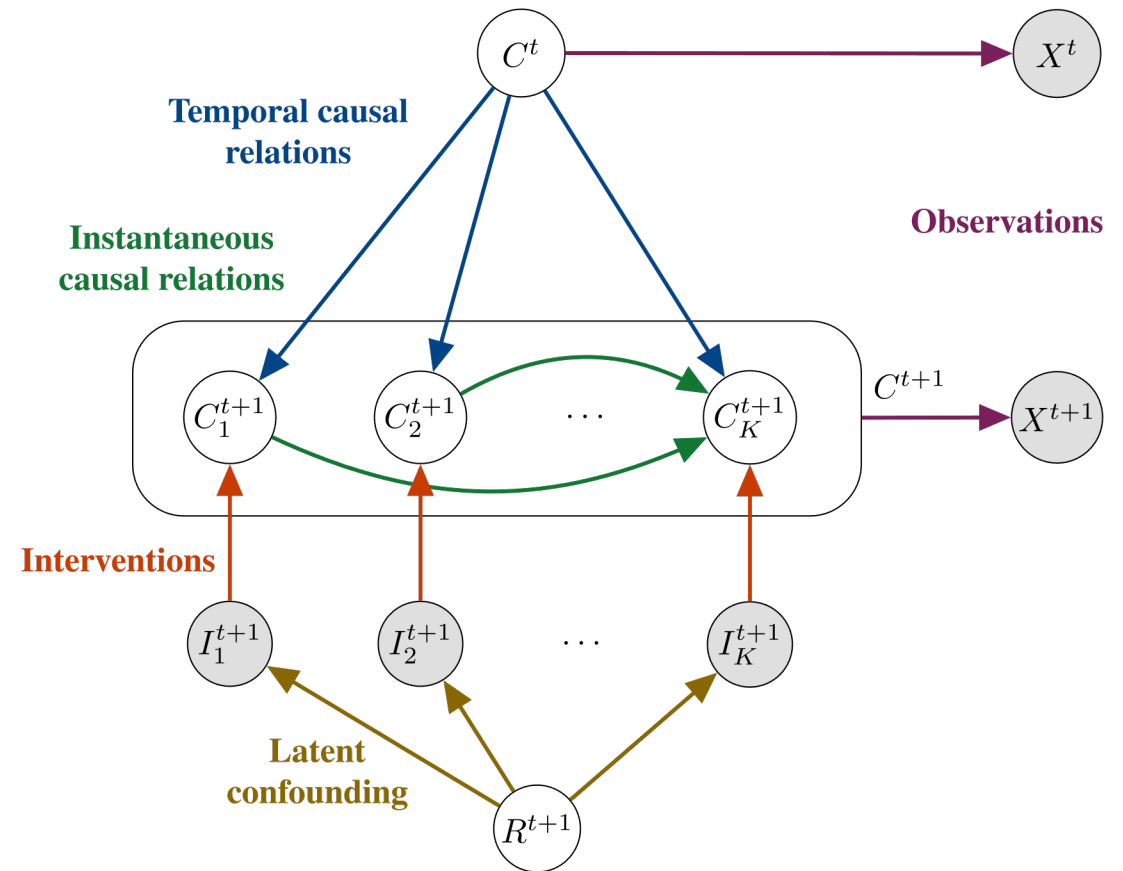
iCITRIS: Instantaneous Effects in Temporal Sequences
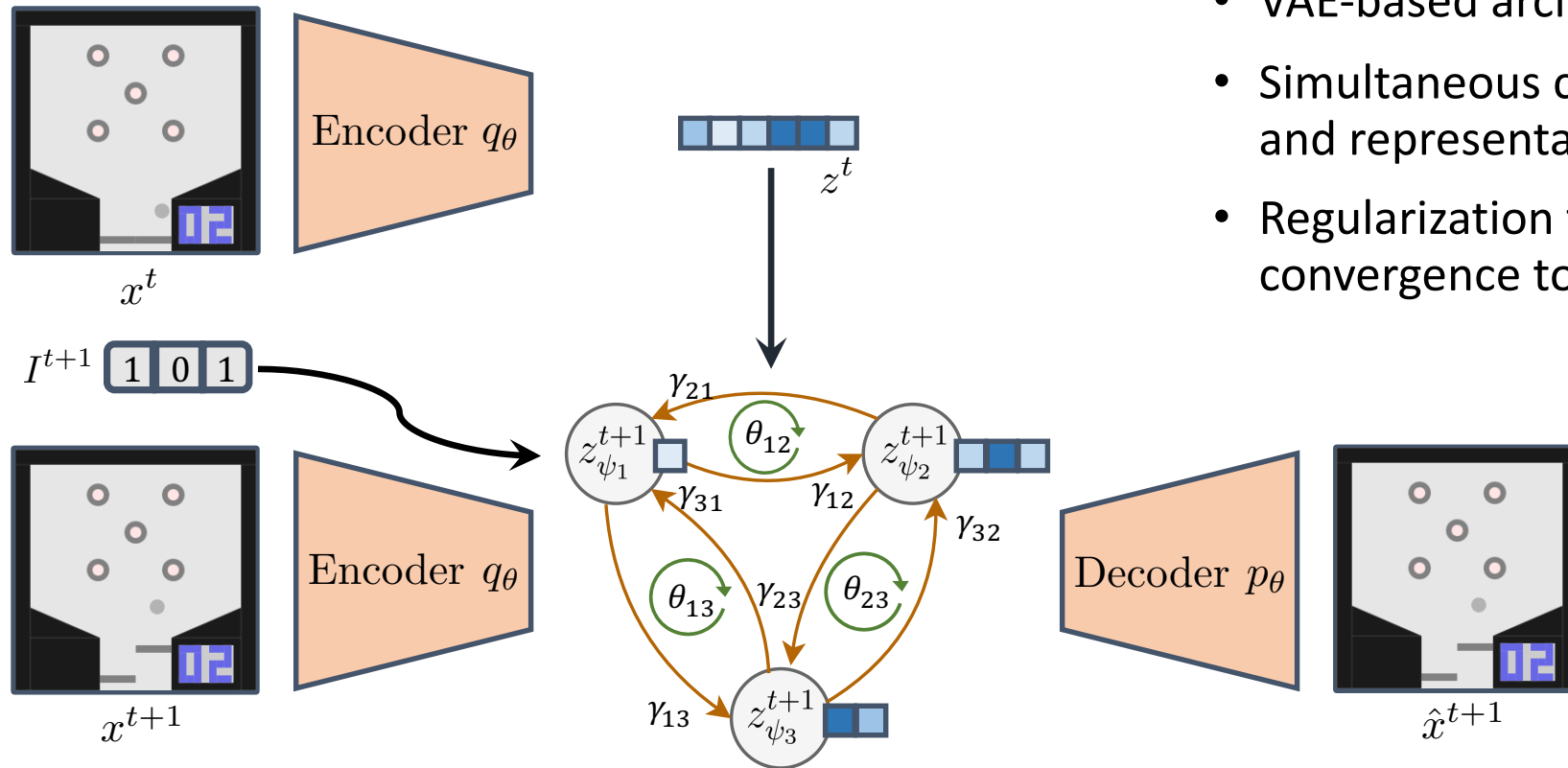## Setup

- Many more pitfalls, e.g.:

$$p_1(C_1)p_2(C_2) \quad \text{vs} \quad p_1(C_1)\hat{p}_2(C_2 + C_1|C_1)$$

- Solution: *partially-perfect* interventions that remove instantaneous parents

  ⇒ Minimal causal variables [Lippe et al., 2022] become identifiable

- Chicken-and-egg situation:
  - Without graph, no causal variables
  - Without causal variables, no graph

Lippe, Phillip, Sara Magliacane, Sindy Löwe, Yuki M. Asano, Taco Cohen, and Efstratios Gavves. "CITRIS: Causal Identifiability from Temporal Intervened Sequences." In International Conference on Machine Learning, PMLR, 2022.
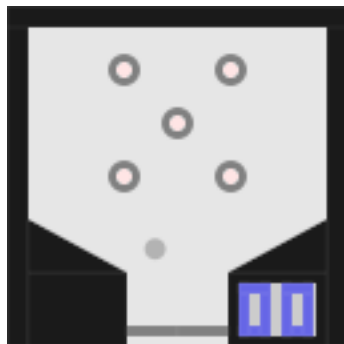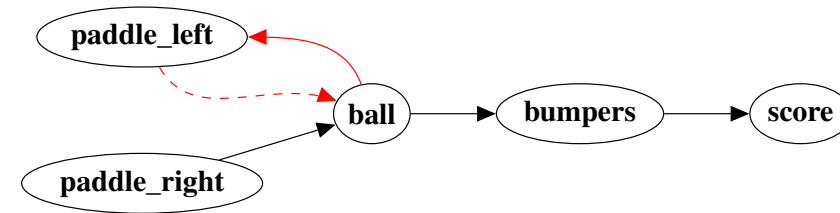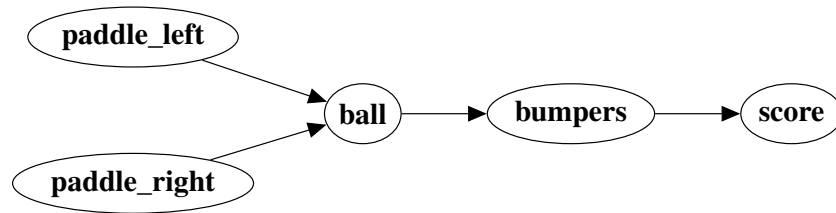
iCITRIS Architecture

- VAE-based architecture
- Simultaneous causal discovery and representation learning
- Regularization to prevent early convergence to local minima

Experiments
Causal Pinball

Learned Instantaneous Causal Graphs

Model	R^2 (diag ↑ / sep ↓)	SHD (instant ↓ / temp ↓)
iCITRIS-ENCO	**0.99** / 0.12	**0.67 / 3.00**
iCITRIS-NOTEARS	0.98 / 0.18	3.33 / 4.67
CITRIS	0.90 / 0.39	3.00 / 7.67
iVAE	0.44 / **0.05**	4.33 / 4.67
iVAE-AR	0.47 / 0.15	8.00 / 3.67

Conclusion

- Causal Representation Learning tries to find the latent causal variables and their relations

- **Instantaneous Effects**: Effects that occur faster than the frame rate

- We proof the identifiability of causal variables under partially-perfect interventions

- **iCITRIS**: End-to-end learning of causal representations from temporal sequences
  - Joint causal discovery and causal representation learning
  - Regularization to prevent early convergence to local minima

Paper and code