Physical Reasoning in an Open World

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Closed world physical reasoning

Most physical reasoning – in scientific computation, AI, and cognitive psychology experiments and models – operate in a closed world.

The problem statement fully specifies [up to some level of description]

- the initial situation
- the dynamic theory
- the exogenous events/boundary conditions.

In particular, simulation/physics engines assume a closed world.

Open world reasoning is important

- You pack clothes in a duffel bag, you lock the zipper, you check it onto a flight to Chicago. The duffel bag is lost. Three days later, it turns up at the Dallas airport, scuffed up, but intact. If it’s still locked, you can be sure that the clothes are still inside.

Open world reasoning

Beads and twine are found at an archaeological site in Alaska

The beads were manufactured in Venice in the 1400s.

The twine was made from plant materials in Alaska, carbon-dated to the 1400s.

Infer that the beads were brought overland through Asia and across the Bering Strait.

Open vs. closed world is a matter of degree

- Deterministic prediction
- Probabilistic / adversarial prediction
- Partially observable states
- Qualitative envisioning
- Inverse reasoning
- Radically incomplete reasoning

Reasoning about containers

In a toy microworld of objects, containers, and lids,

given initial specifications:

- Partial characterization of states at various times.
- Partial enumeration of actions.
- Constraints that specified actions *do not* occur.

Goal: Make sound inferences about later states.

Proof-of-concept implementation in Prolog.

Need work-arounds to get negation to play nicely with unbound variables.

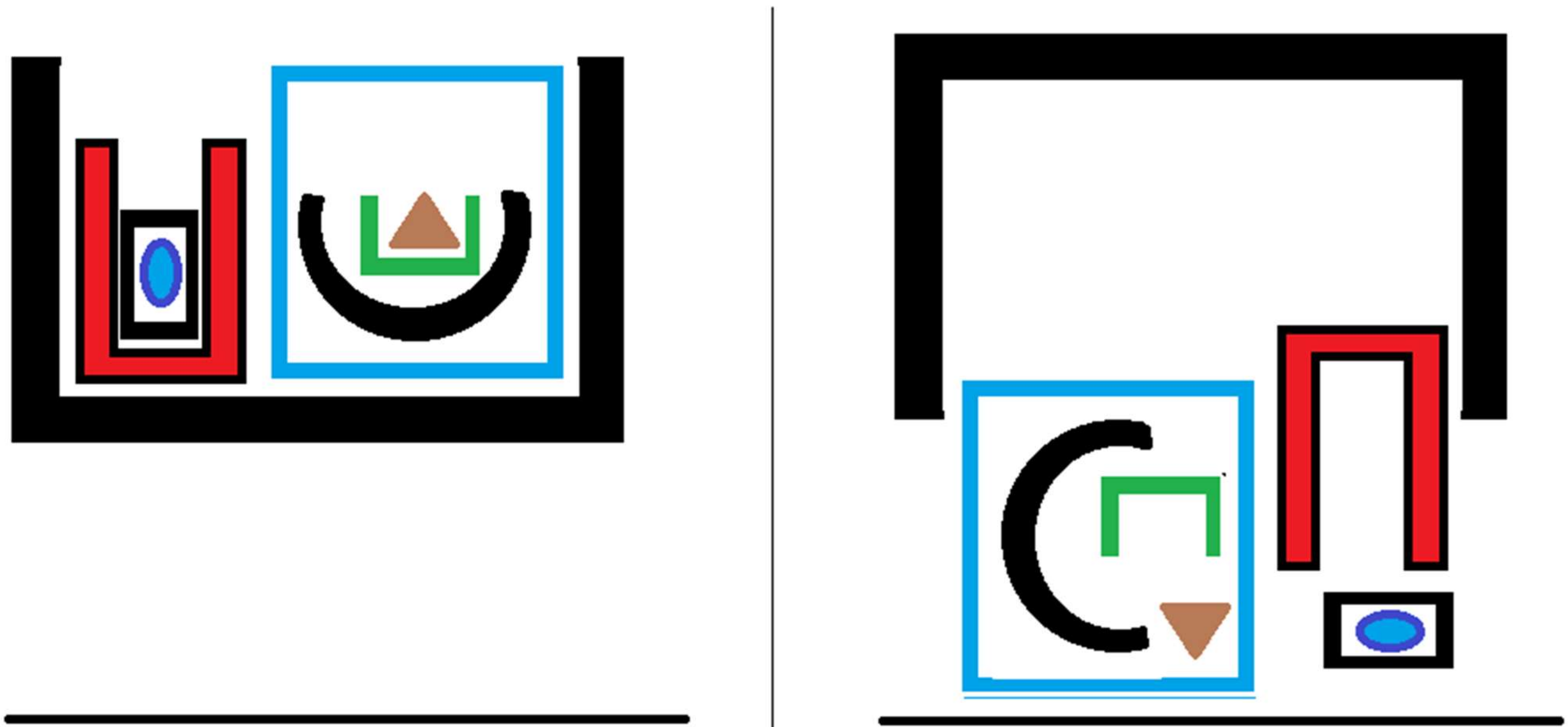
Microworld

Sorts: Objects, Times, Locations, Actions.

Objects: closedContainer(O), openContainer(O), lid(O), containerWithLid(O), block(O).

Actions: load(OB,OC), unload(OB,OC), seal(OC,OL,O), unseal(O,OC,OL), carry(OB,LFROM,LTO), dump(OC).

Dumping



Before

After dumping

Example

t0 < t1 < t2 < t3

1. [t0,t1] Load oa into open container oc.
2. [t1,t2] Seal oc with lid ol forming lidded container ocl.

Constraint: oc is not unsealed between t2 and Tt3.

Infer: oa is still inside ocl at t3.

Without the constraint, the inference is invalid.

Second Example

t0 < t1 < t2 < t3 < t4

1. [t0,t1] Object oa is loaded into open container ob.
2. [t1,t2] ob is loaded into open container oc.
3. [t3,t4] oc is carried to location l.
4. [t4,t5] oc is dumped.

Constraint: oc is neither unloaded nor dumped between t2 and t3

Infer: oa is at location l at time t5

Future work

Extend the kinds of information and the scope of forms of uncertainty.

- Asynchronous events; partial ordering on timeline.
- Indeterminate sets of objects
- Spatial information.

Other physical domains.