

Exploring how the geometry of the representation space influences curiosity-based exploration

Nils Ruet, Tonglin Yan, Dimitri Ognibene, Kenneth Williford, David Rudrauf, Grégoire Sergeant-Perthuis

How does geometry influence exploration behaviors?

In human spatial awareness...

- 3D Projective geometry structures information integration and planning
- Subjective perspectives can be taken on this internal representation space

Methodology

- Agent a looks for an object O using observations $y_o \in Y$.
- Agent's "internal world model" space X is a group structured space, where a group acts on it. We compare spaces structured by Euclidean Geometry vs Projective Geometry.
- The agent plans its actions m by taking perspectives on its internal G-space X , corresponding to the choice of a group action.
- Beliefs P_X about the position of object O = probability measure on the internal space.
- Uncertainty of observations = Markov Kernel $P_{Y|X}$. Updated beliefs $P_{X|y_o}$ are computed using Bayes' rule.

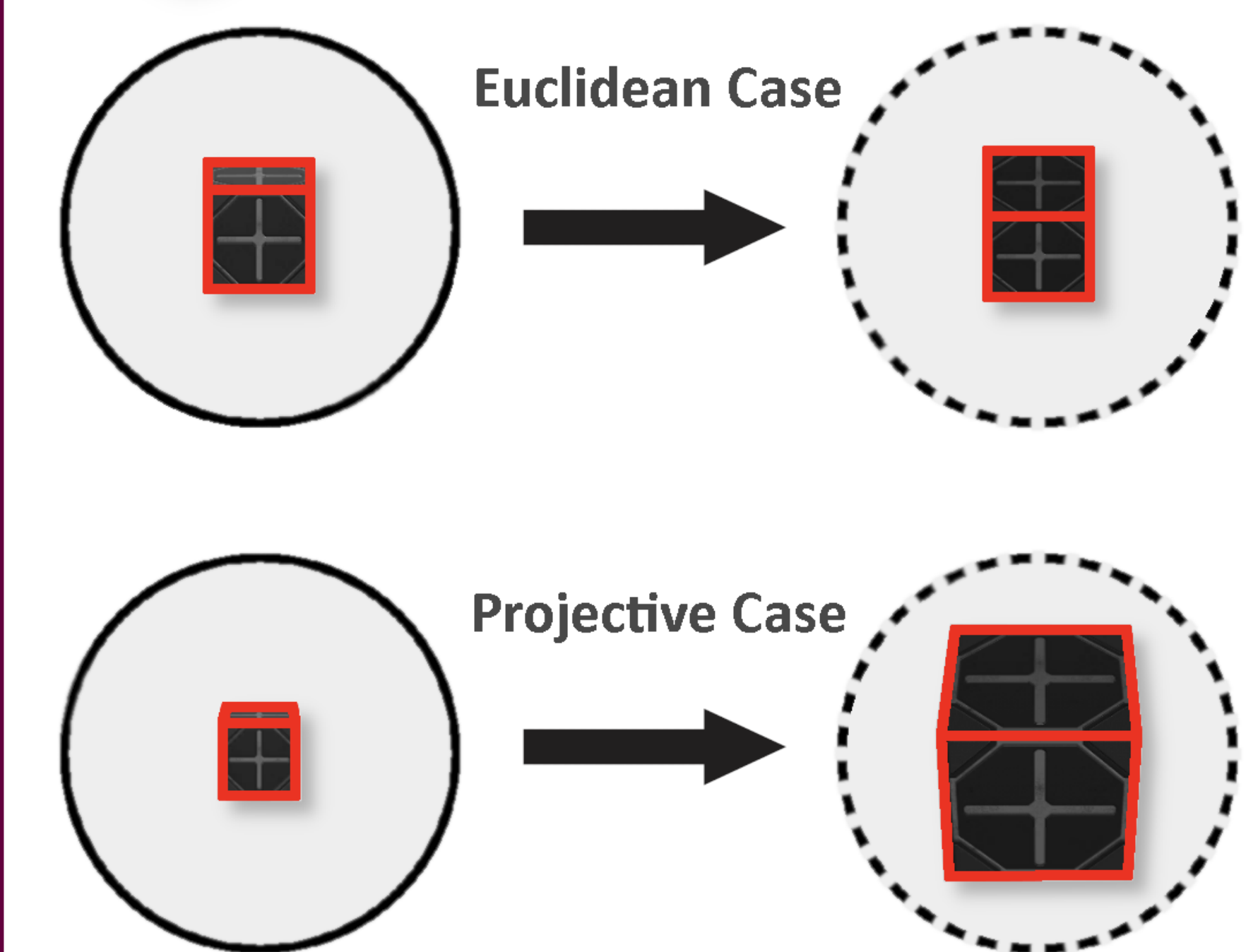
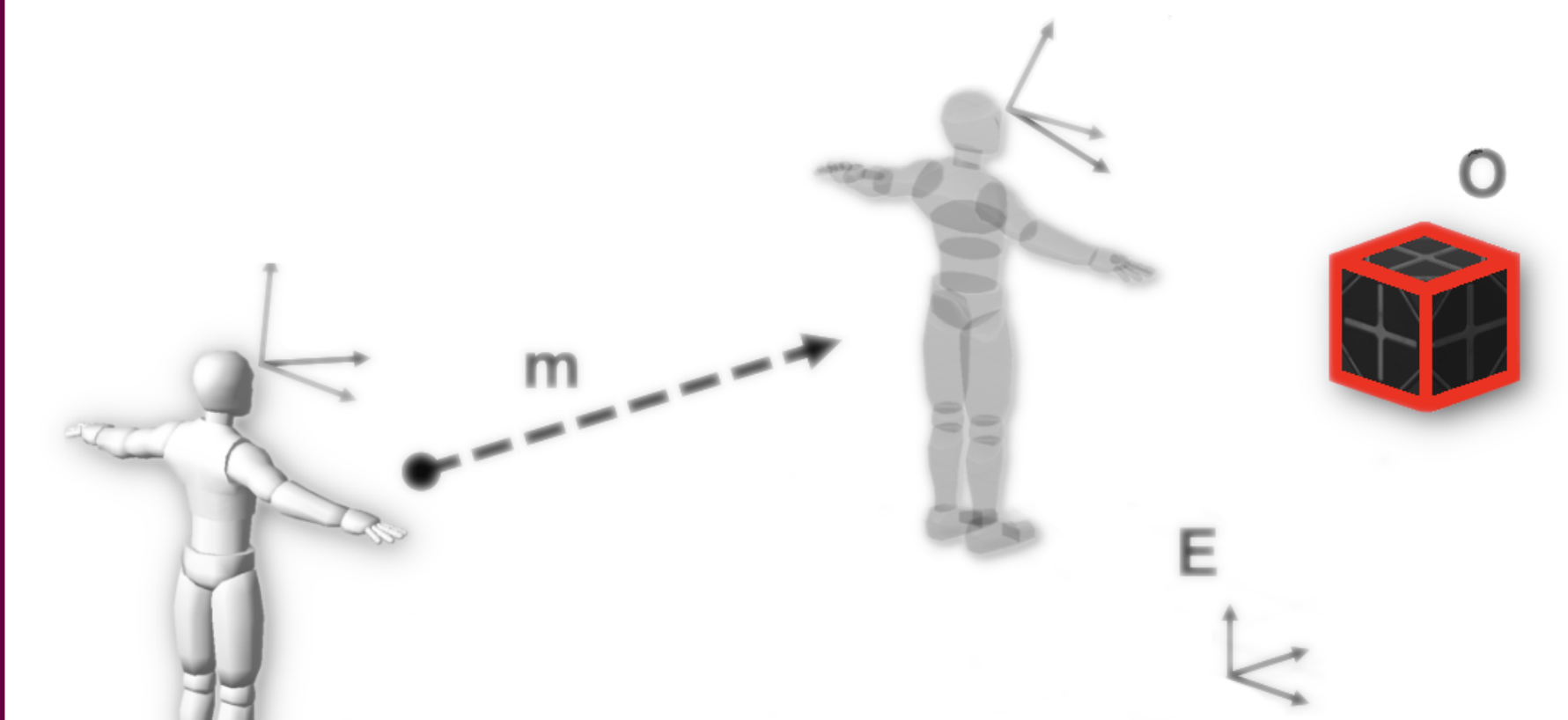
Epistemic value and exploration algorithm

- Epistemic value/curiosity C = divergence H between prior and posterior beliefs (from Active Inference)

$$C(P_X) := \mathbb{E}_{P_Y} [H(P_{X|Y}|P_X)] \quad (1)$$

- A broader belief distribution yields a greater epistemic value
- The agent maximizes at each step the epistemic value of the posterior beliefs.

Setup of toy model



Approaching a point in projective geometry **magnifies** the surrounding space.

Results & discussion

I. Geometry can induce a drive to approach the object

Euclidean case : the agent **stays still**

Viewpoint doesn't affect the **broadness of beliefs**: epistemic value is **constant** w.r.t. movement

agent



object



agent

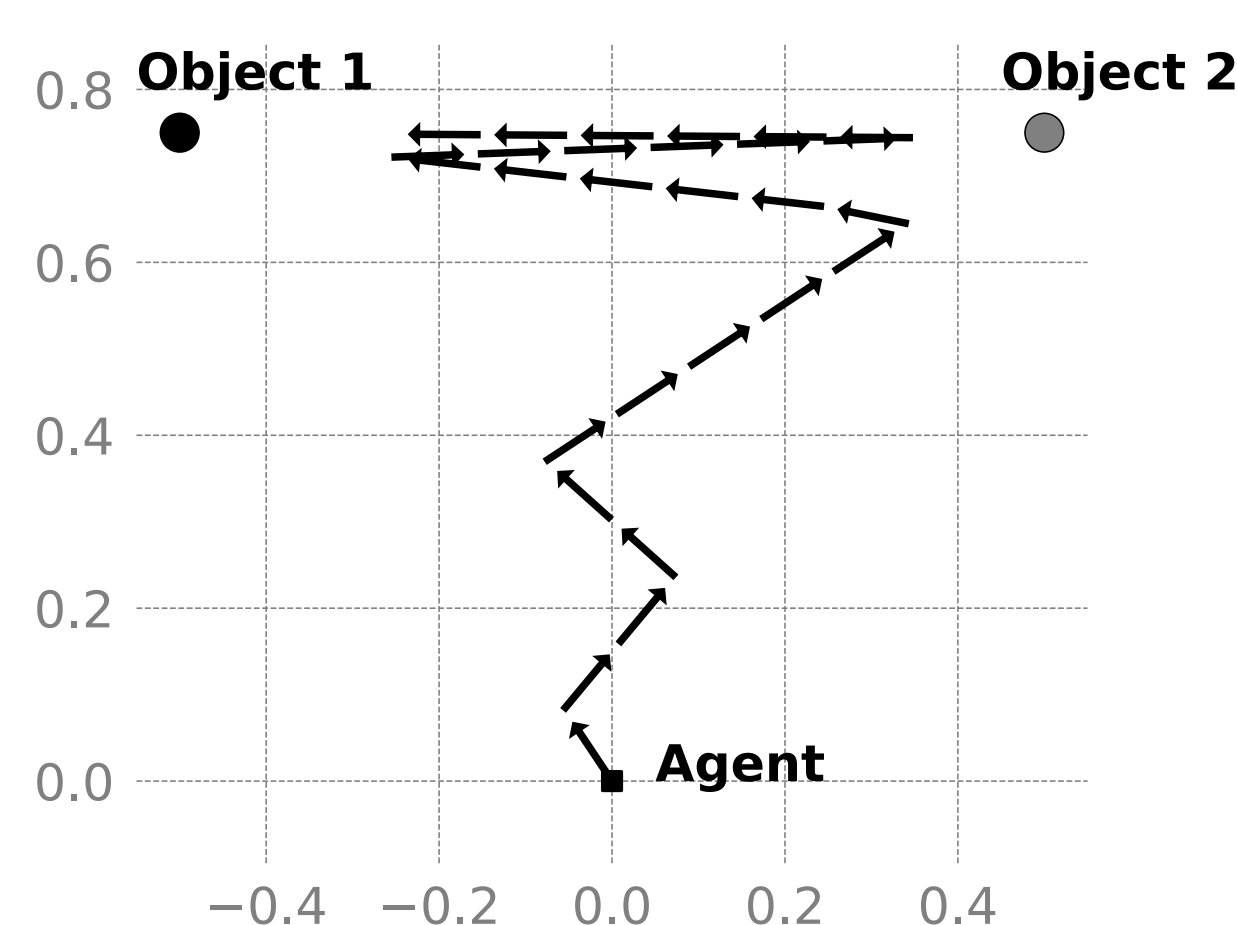


object

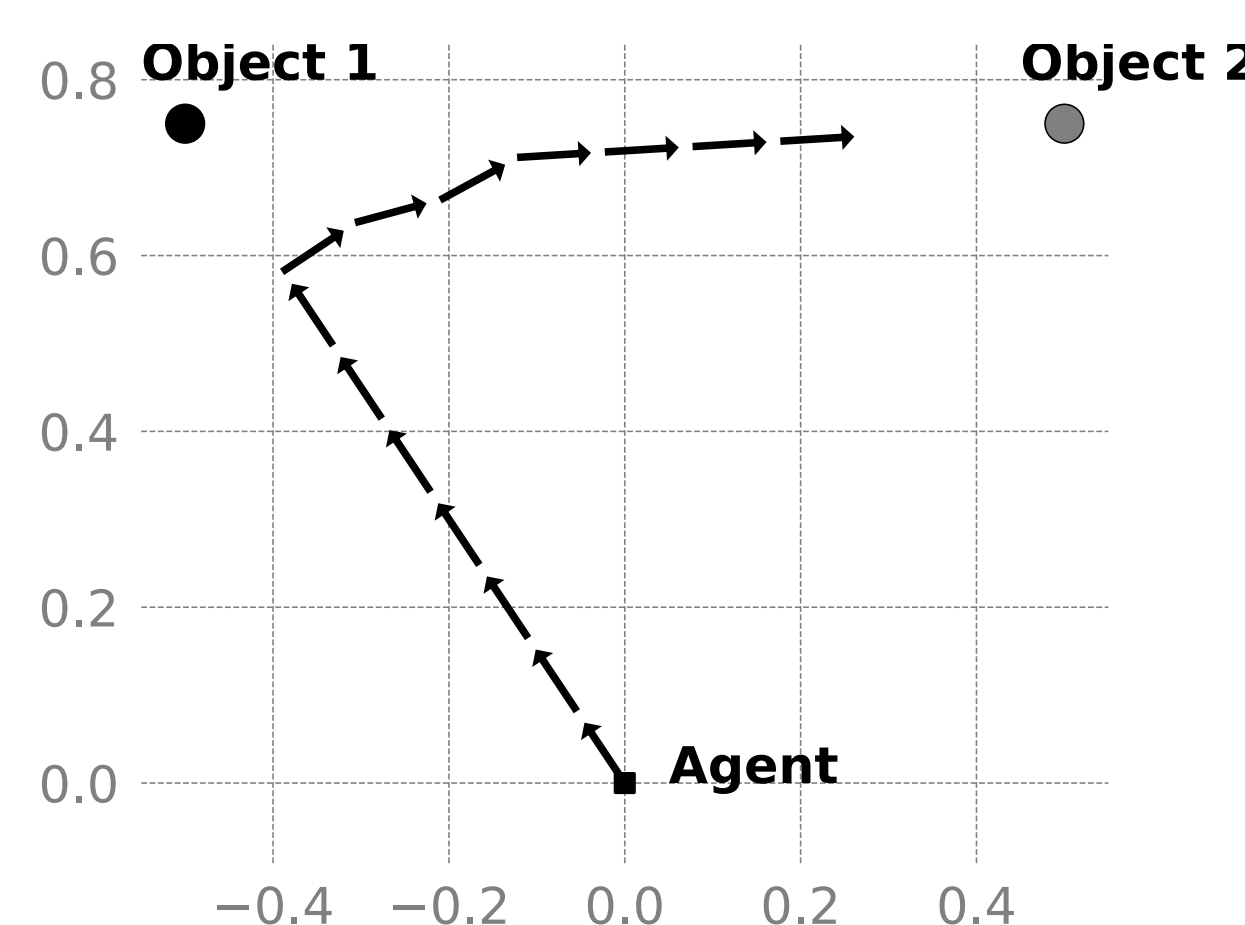


II. Exploration behaviors in multi-object projective settings

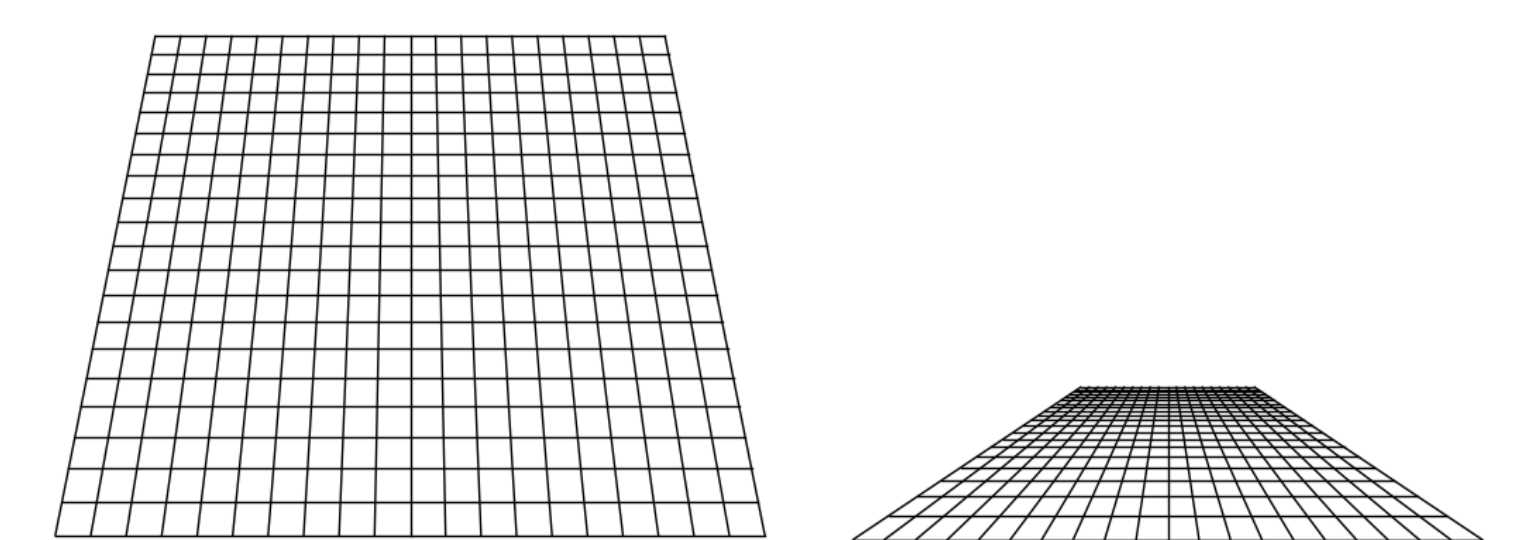
- Observing an object **weakens the drive** to approach it as the **epistemic value decreases** (the belief distribution narrows with evidence)
- Projective geometry** : **approaching the object increases the epistemic value** (surrounding space is magnified = broader beliefs)
- Strong projective deformation = **amplified magnifying** = higher drive to approach. This drive may compensate the decrease in epistemic value from the observations.
- Altering the **magnitude of the projective effect** results in **different exploration behaviors**



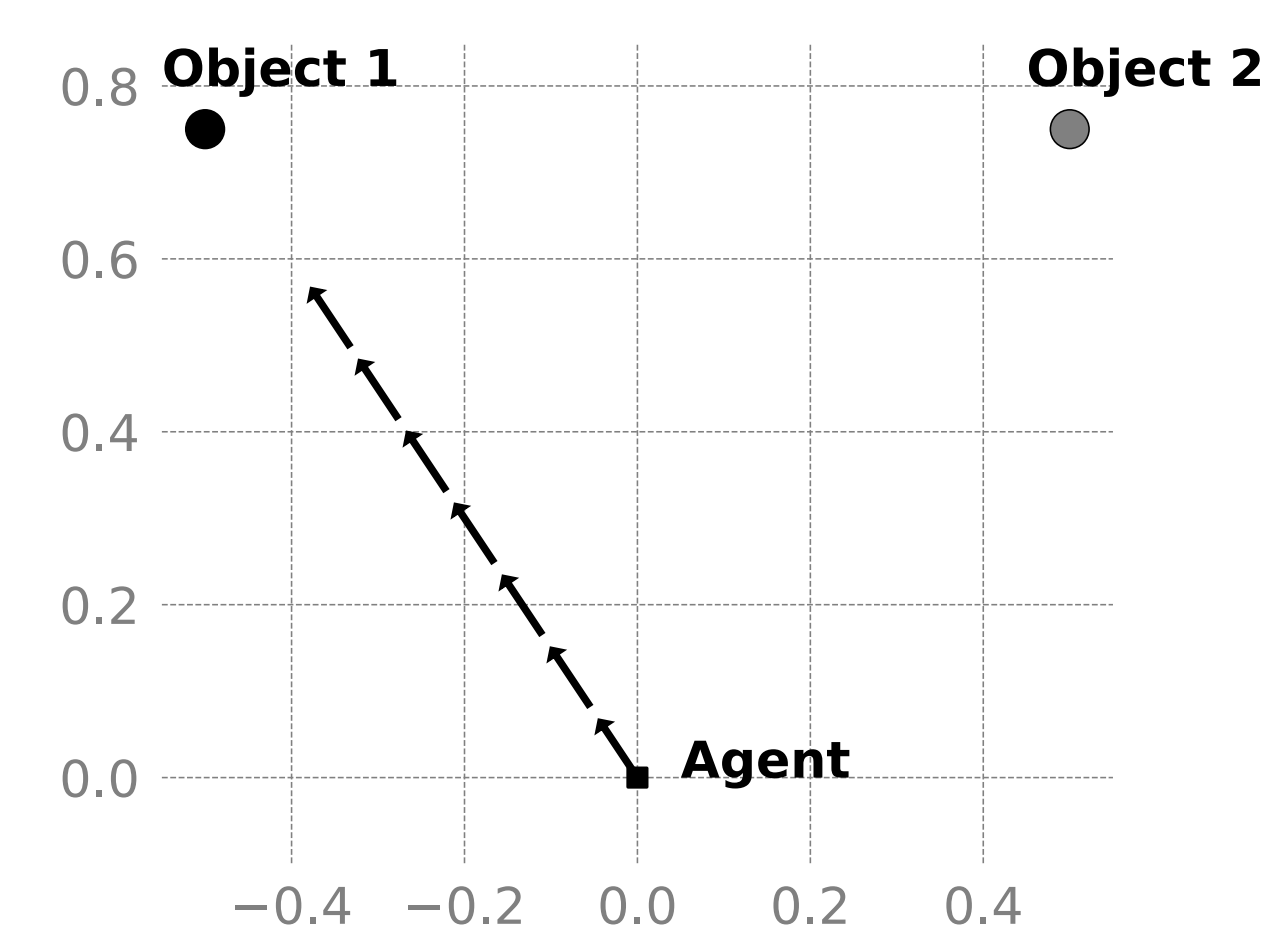
Weak projective deformation = lower drive to approach = quick oscillation between objects



Moderate projective deformation = low-frequency oscillation



*Weak vs strong projective deformation of the euclidean grid. The **magnifying effect** on approach is **amplified with greater deformations**.*



Strong projective deformation = the drive to approach prevails over the decrease in epistemic value (very low-frequency)

Conclusion

- Projective geometry** generates an **epistemic drive to approach an object**
- The **magnitude of projective deformations** can be interpreted as **modulating the agent's focus on a target**.

