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Affordances: A Knowledge Representation towards Human-Robot Interaction

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Introduction

Goal: Can we make the **representation** process of the agent's action possibilities **autonomous, meaningful, trackable, and explicit?**

Objective: Design of inference mechanisms and patterns for **affordance representation** in the robot's knowledge base

Scenario:

- Shared goal manipulation task between human and robot in a kitchen environment
- Actions: take, place, put in, give, hand-over, make reachable (bring closer), pour, ...
- Example: Prepare a recipe or cleaning the table

Background & Formalism

Capability: "the ability to carry out a type of activity"[1]

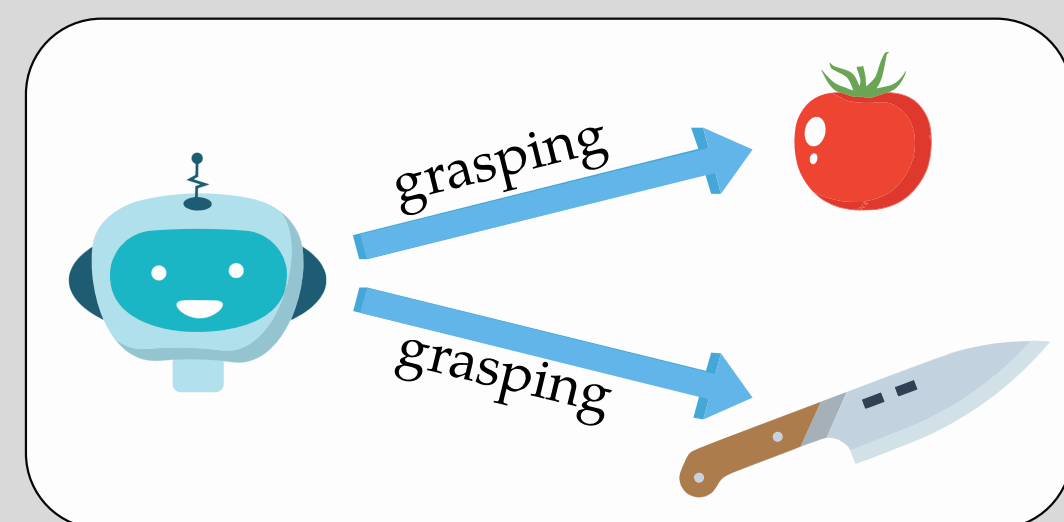
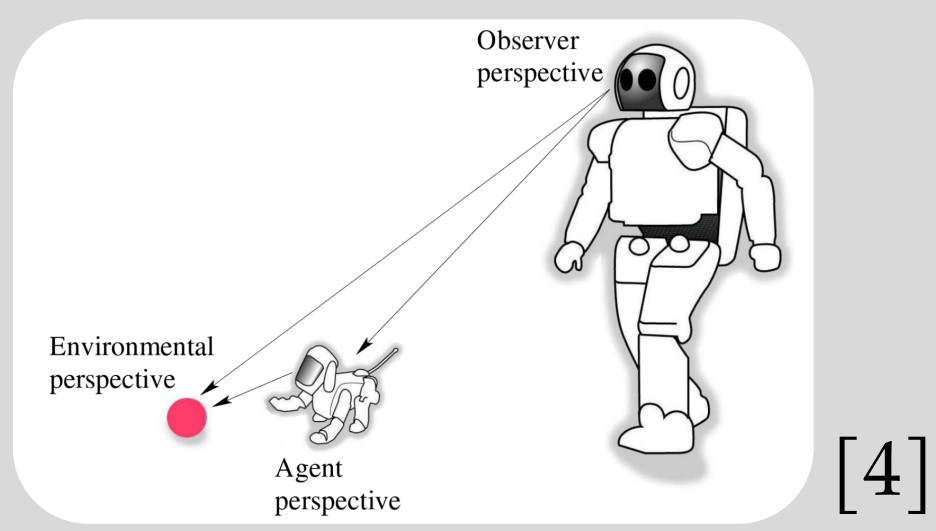
- Agents can have different capabilities given their configurations (embodiments)
- Combinations of capabilities can enable higher-level capabilities

Disposition: "the property of a thing that is a potential"[2]

- Objects can have dispositions, which can be linked to particular sub-parts
- Conceptual equivalence: objects can be referred to by dispositions (not only by class)

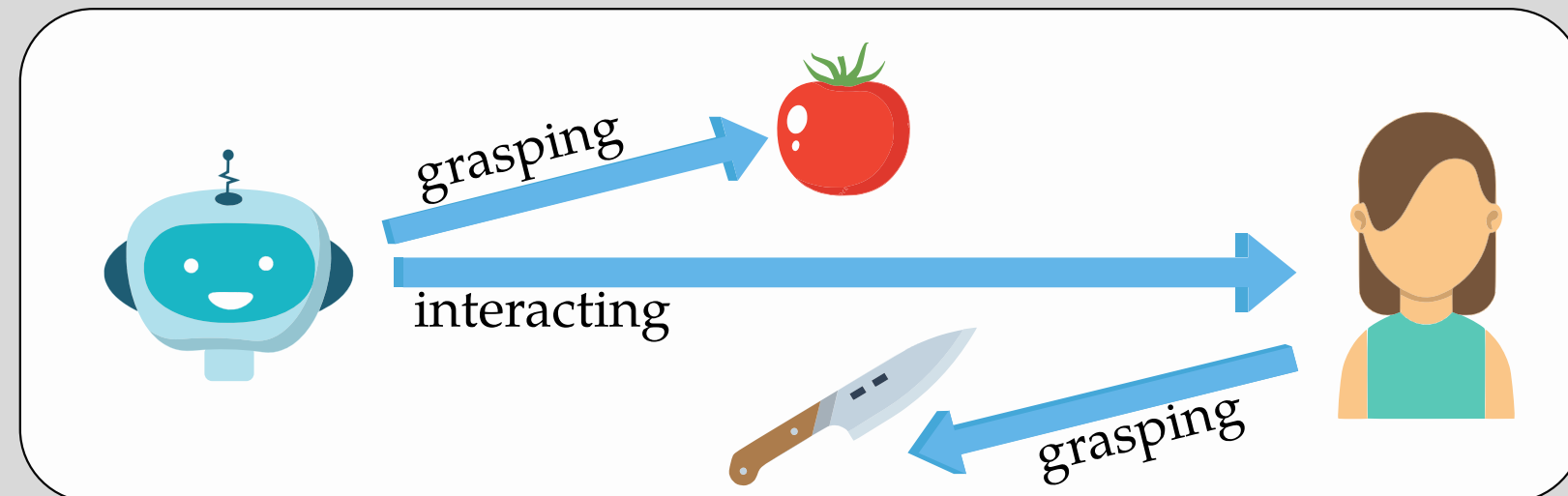
Affordance: "What the environment offers to the animal, either for good or ill"[3]

- Opportunities for action within an agent-environment system
- Affordances stem from the "fit" between agent's **capabilities** and entity's **dispositions** :



Social Affordance: "Social affordances are possibilities for social interaction or possibilities for action that are shaped by social practices and norms"[5]

- Opportunities for action within a multi-agent system
- Widens the action possibility range of agents by providing new ways of actualizing a given disposition using other agents



Knowledge Base: Ontology

- "formal specification of a shared conceptualization" allowing to define concepts, individuals, and relationships.
- E.g: clara is an individual of the class Human and is linked to the individual fred by the property hasBrother
- Enables DL-logic reasoning processes to infer new knowledge

Affordance formalism: Chemero's

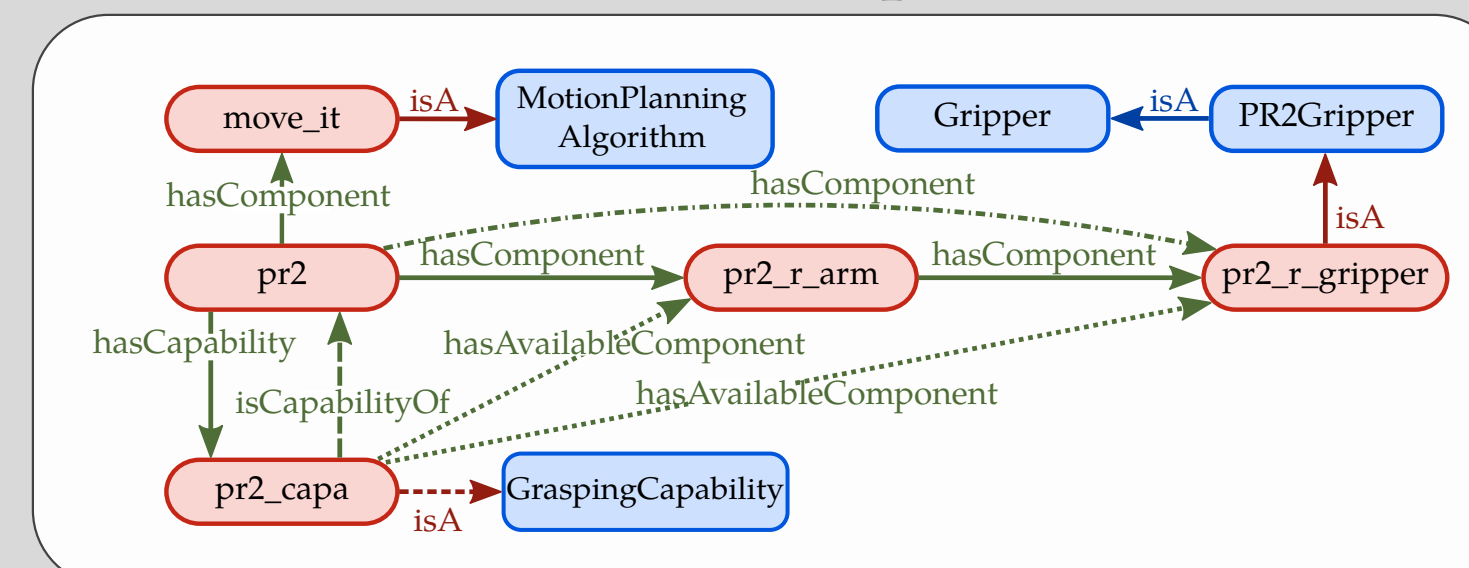
- Relational view: $Affords-\Phi(feature, ability)$
- Φ is a behavior, *feature* is an entity's disposition and *ability* an agent's capability
- E.g grasping behavior, graspable disposition and grasping capability)

Representation of Capability & Disposition

Capability:

- Inheritance relations over a single individual representing the agent's capabilities (pr2 hasCapability pr2_capa)
- Inference mechanism according to equivalent classes defined as the possession of subsets of components

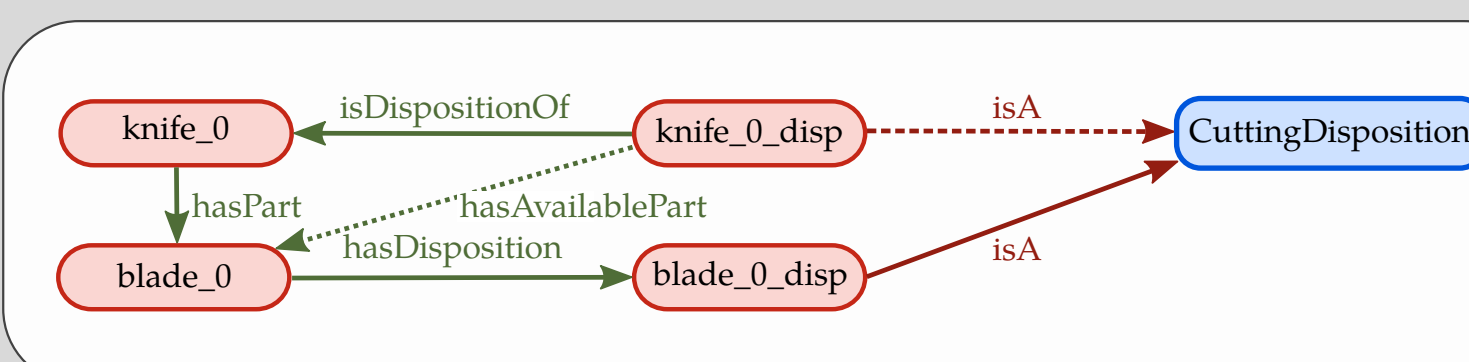
GraspingCapability \equiv hasAvailableComponent some (Gripper and MotionPlanningAlgorithm)



Disposition:

- Similar pattern as for Capability, a single individual represents the object's dispositions (knife_0 hasDisposition knife_0_disp)
- Objects can be composed of subparts which can provide the object with a given disposition

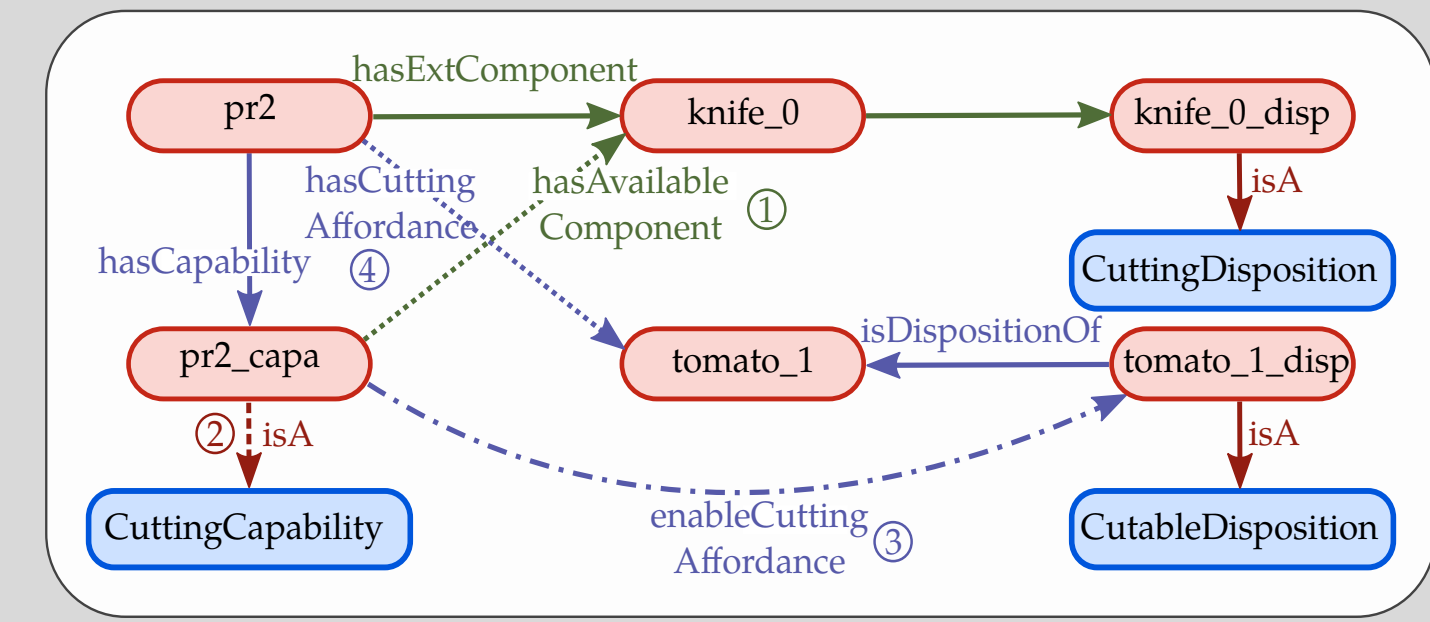
CuttingDisposition \equiv hasAvailablePart some (hasDisposition some CuttingDisposition)



Representation of affordances Agent-Object(s)

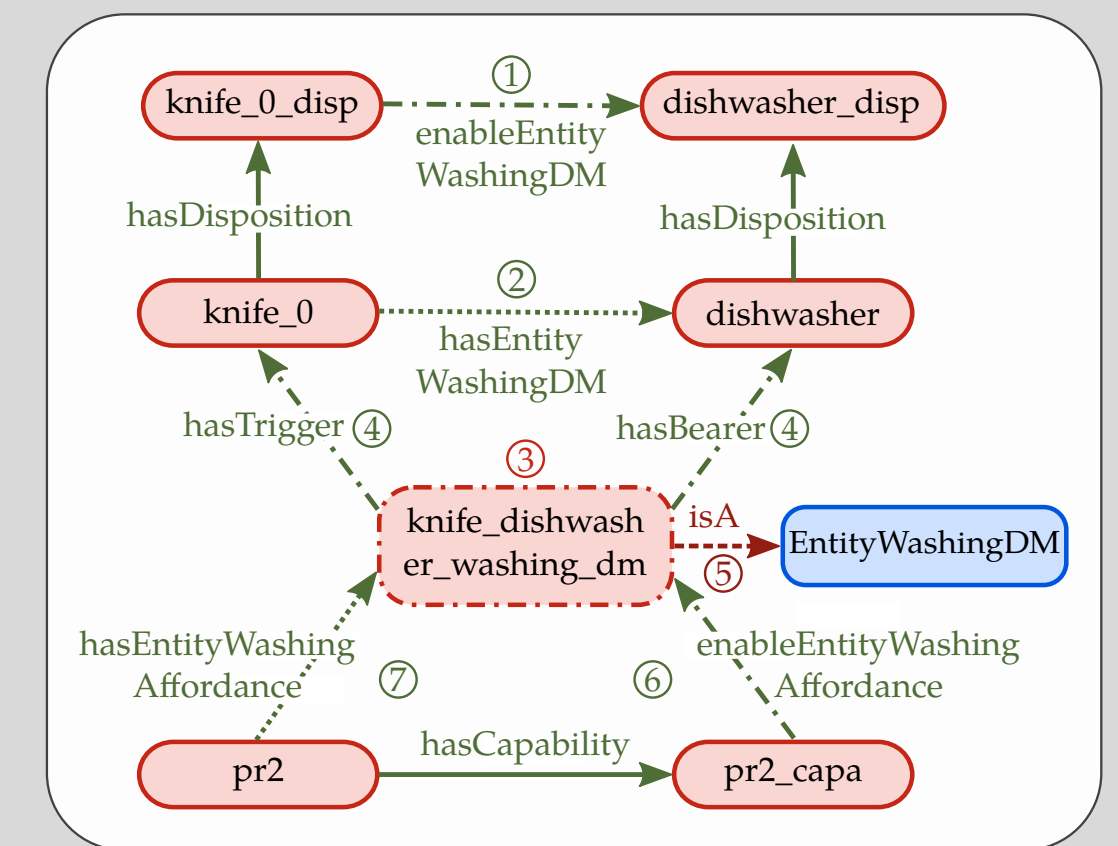
Affordance agent-object:

- The match between capabilities and dispositions enable the affordance relation to be created between the agent and the object
- Agent-tool systems bring new affordances through the acquisition of a new capability provided by the tool (functional affordance)
- E.g: pr2 hasCuttingAffordance tomato_1



Affordance agent-dispositional match:

- The reciprocal dispositions of objects create an individual encompassing the involved dispositions and the interacting dispositions
- Dispositional Match (DM): "partners for a mutual manifestation that is their common product"[6]
- Trigger/Bearer roles
- E.g: pr2 hasXAffordance knife_dishwasher_dm

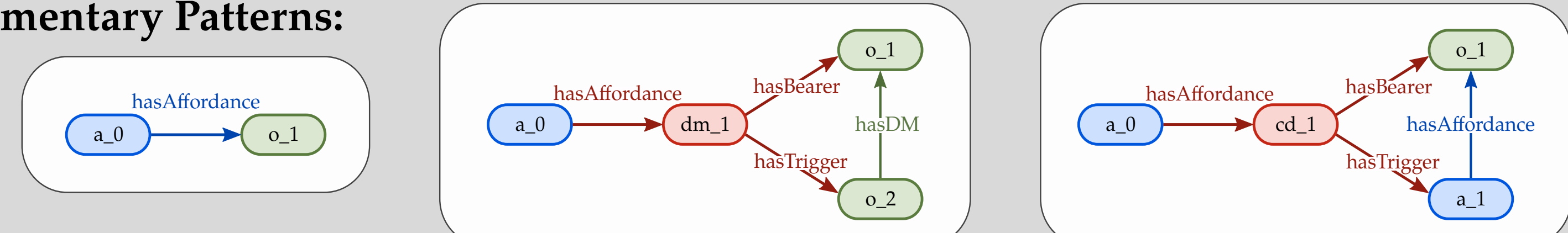


Representation of Cooperative Affordances

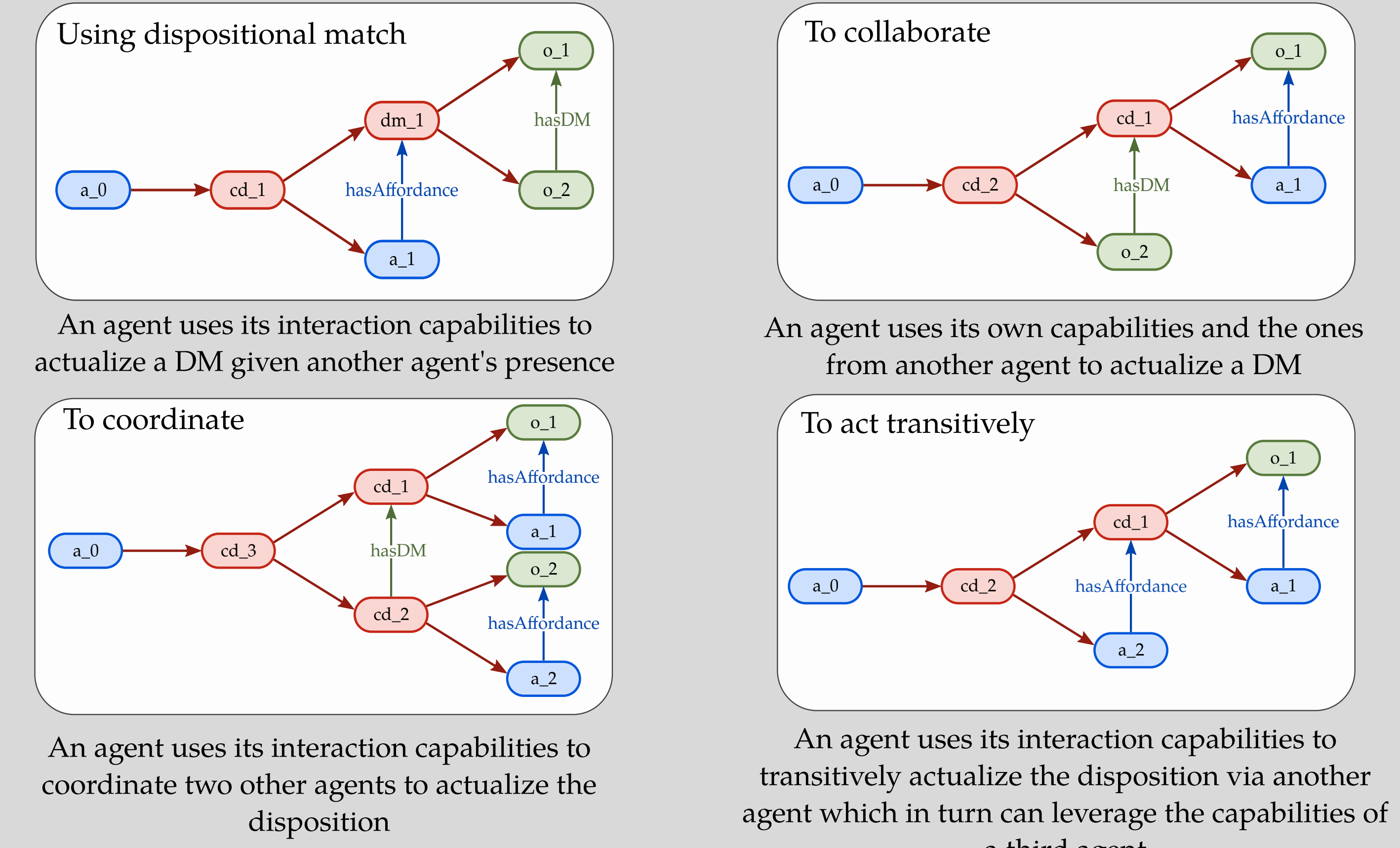
Cooperative Affordance:

- Affordance in multi-agent systems which allows for an agent to actualize a given disposition by using the other agents in its environment, even if it doesn't have the required capability to act directly upon the entity
- E.g: an agent wanting to move a heavy object could leverage the presence of another agent with sufficient lifting capability
- Cooperative dispositional match (CD): An agent's capability can be seen as a reciprocal disposition to an object's actualizable disposition

Elementary Patterns:

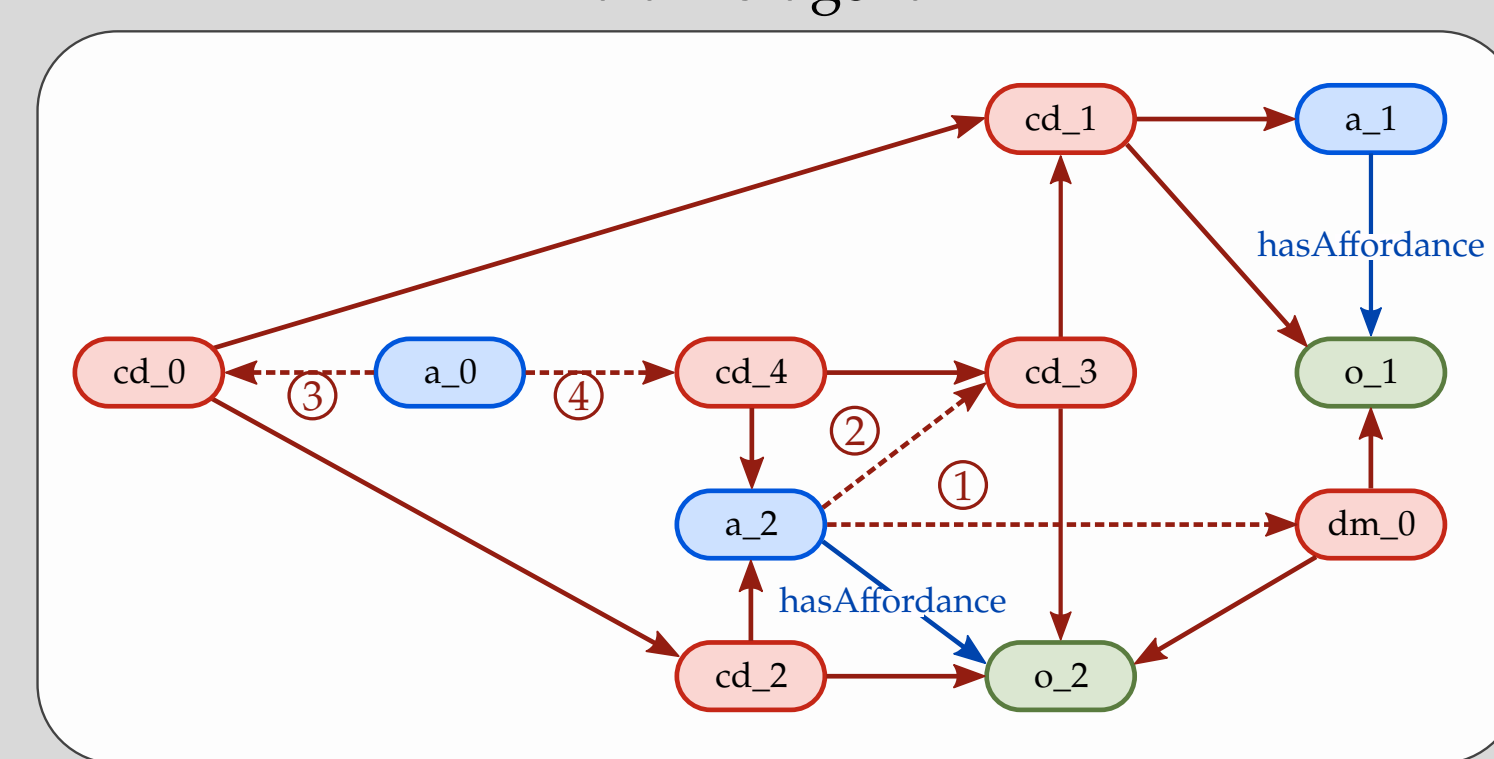


Combined Patterns:



Overview of combined patterns:

- Cooperatives affordances can be used to actualize the disposition of a given entity by several means
- E.g: the dispositions of o_1 and o_2 can be actualized in 4 different ways given the perspective of one agent



Discussion

Affordance ontological representation:

- Represent/Infer simultaneously the action possibilities of agents in the environment
- Leverage the presence of other agents with the cooperative affordances
- Future works could be to add effect in the representation, for instance to enable planning algorithms to provide a task plan.

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