Multi-Agent Planning Method Using Affordances from Environment

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Presenter's Bio

- **Sawako Tajima** is a graduate student majoring in administration engineering at Graduate School of Science and Technology, Keio University.

- My research area is Artificial Intelligence (AI), especially autonomous agent.

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Collaborative Project

- Our goal

  - Constructing interactive story-type contents generation system

Realizing the characters in the story

This character interaction seems to be useful...

3D Scene

Creator

→ We need to achieve AI characters that can act autonomously

Overview

- Research Objective
  - Reducing the explosion in the number of agents in multi-agent planning

- Proposal
  - A method for efficiently obtaining action sequences by using affordances in multi-agent planning

- Result
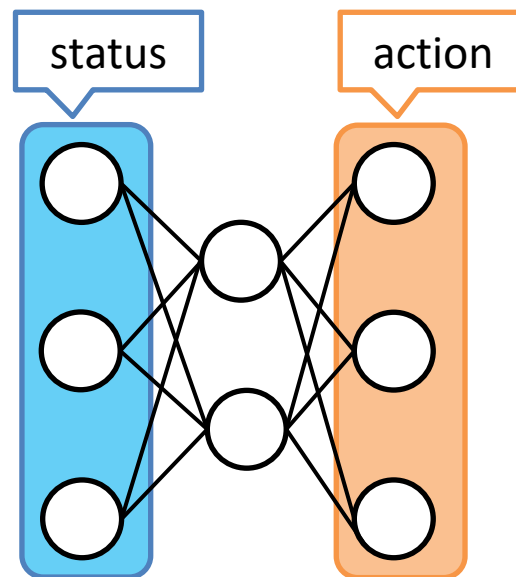 - Efficient planning was possible when affordances were used

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Planning
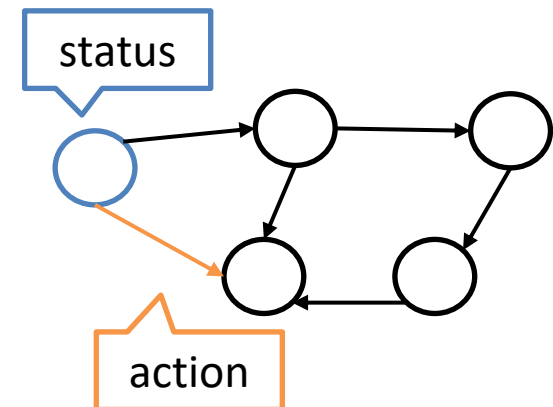
- The process of thinking actions to achieve goals from the environment

Table

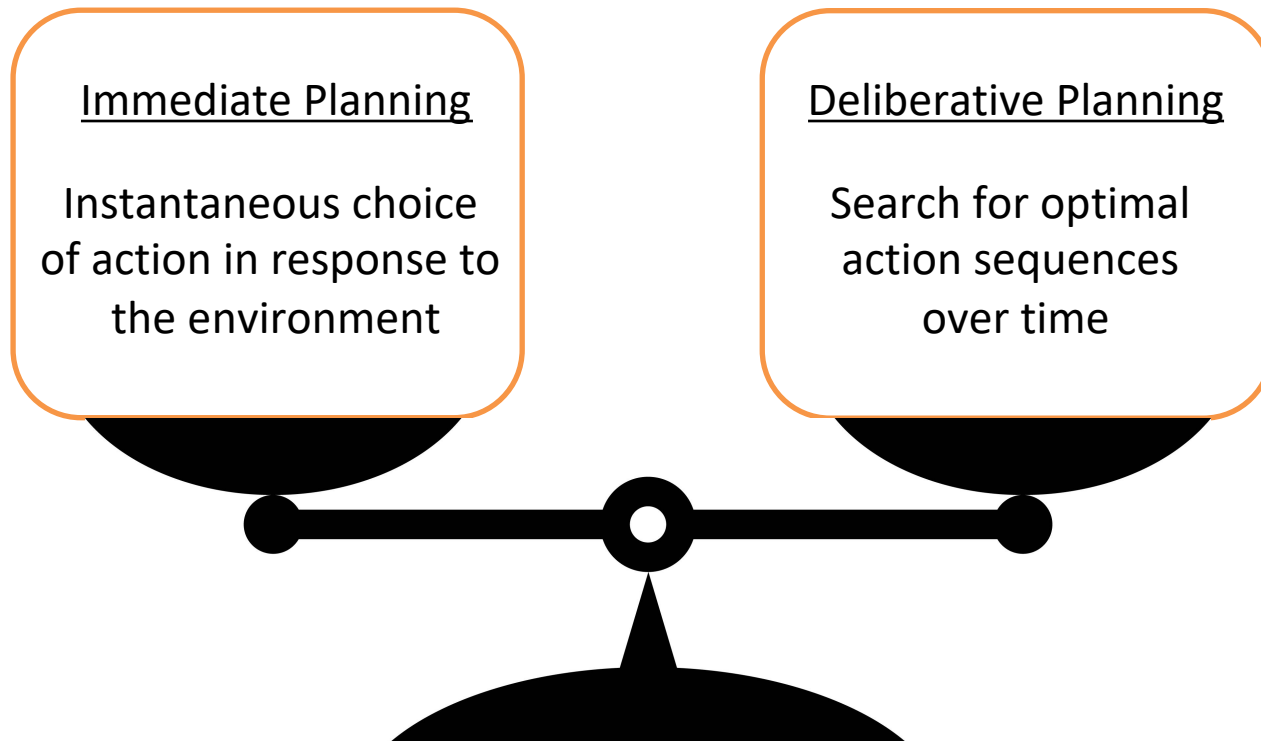| s_t	a_t
s_1	a_1
s_2	a_2
s_3	a_3
s_4	a_4

NN

status   action

Graph

status

action

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Planning

- Responding to dynamically changing environments
  - Need for both immediacy and deliberateness

Immediate Planning

Instantaneous choice of action in response to the environment

Deliberative Planning

Search for optimal action sequences over time
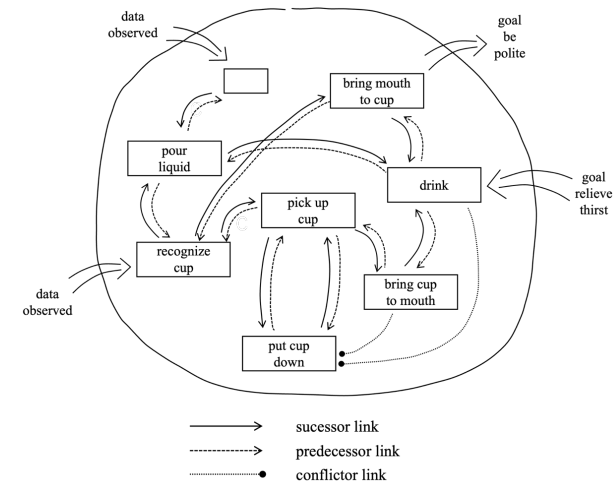
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Multi-Agent Planning (MAP)

- Planning by interaction ($\rightarrow$ in the figure) of agents (equivalent to operants in STRIPS)

- Able to combine immediacy and deliberateness

agent
pick up cup
pick up bottle
drink water
⋮
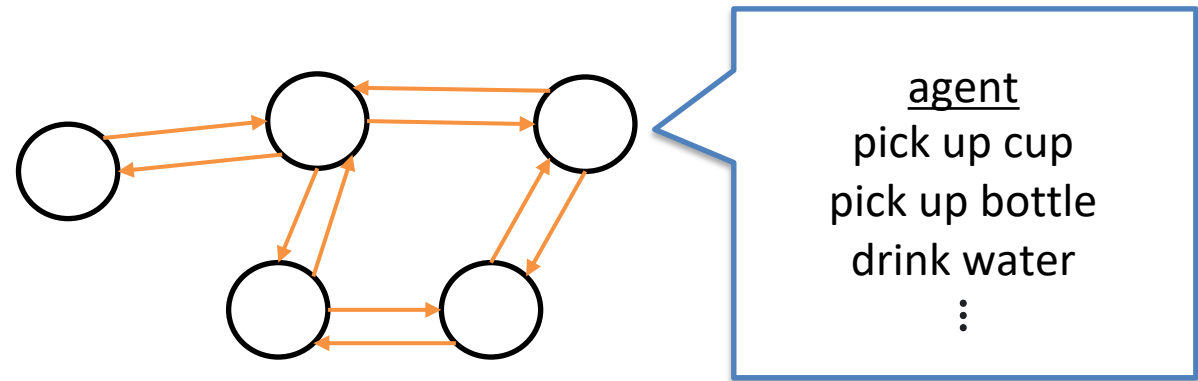
The number of agents is vast when the environment is large
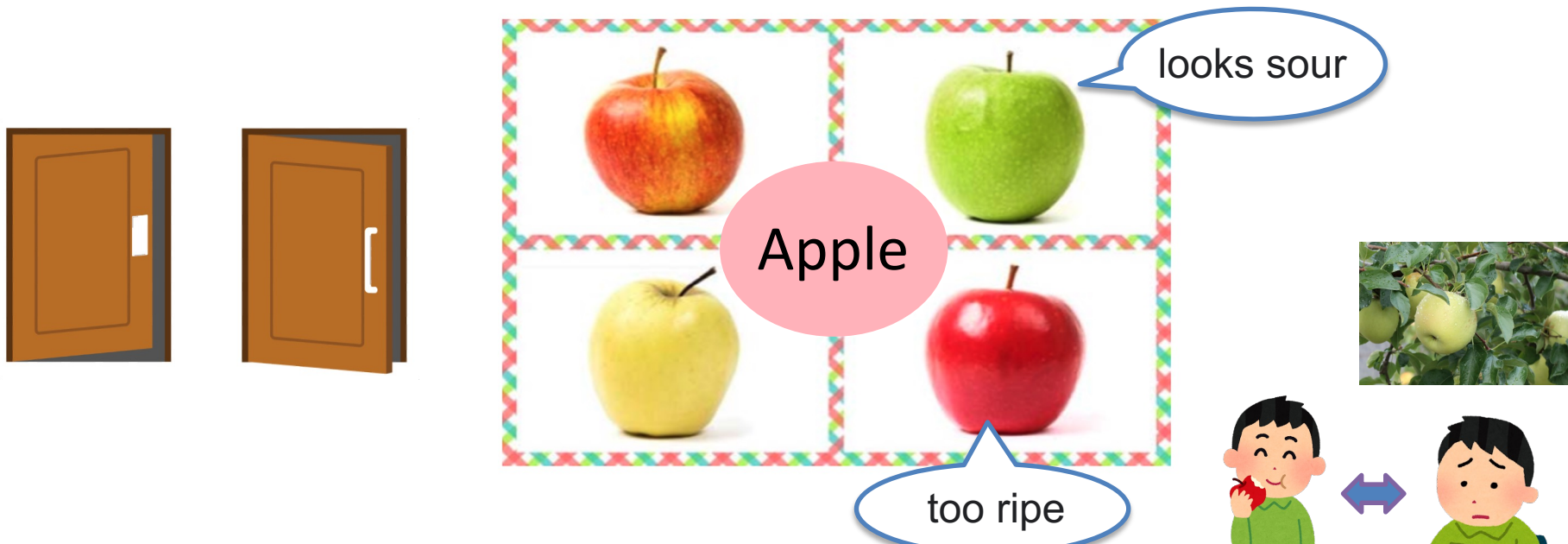→Use affordances

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Agent Network Architecture(ANA)

- ## Advantage
  - Coexistence of immediacy and deliberateness is possible

- ## Disadvantage
  - The number of agents is vast when the environment is large

[2] Pattie Maes, "The agent network architecture (ANA)," ACM SIGART Bulletin, vol. 2, pp. 115–120, July 1991.

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Affordance

- Animals perceive affordances transmitted by objects

looks sour

Apple

too ripe

→Affordances allow animals to reduce wasteful search

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Affordance Network Construction Procedure

GPT-3

Q ： Story about an apple.   A ： He ate an apple.

1. Sentence generation with GPT-3

2. Parsing with CoreNLP
3. Networking dependencies

apple → eat

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Large Language Model (LLM)

The performance of a language model is highly dependent on the size of the model

number of parameters ✕ Amount of training data ✕ computational complexity

LLM, with many parameters and a large amount of training data, can be used for various tasks and is called Foundation Models

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Proposed Method

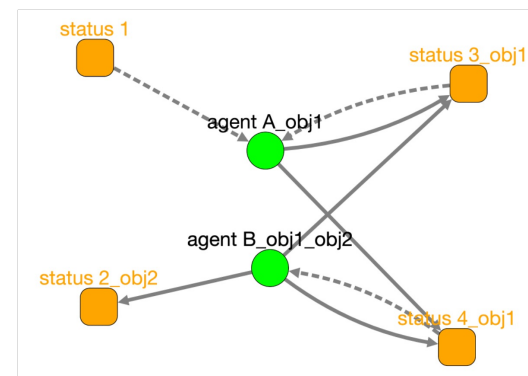- Extending the use of affordances to address ANA issues

(a)Affordance Network

(b)Variable Agent Behavior Network

(c)Agent Behavior Network

A knowledge graph expressing the relationship between a noun (object) and the verb recalled from that noun

ANA's network of agents and states with noun parts as variables

A network with a concrete object assigned to it
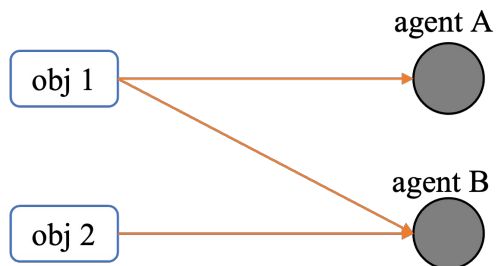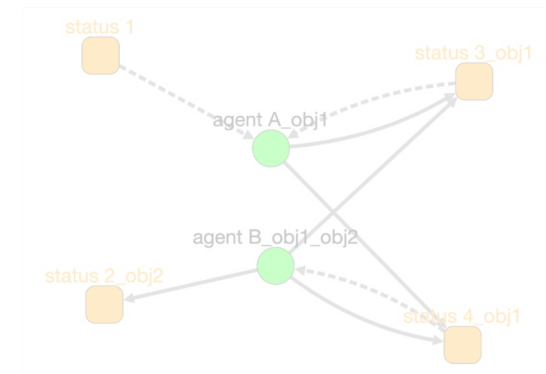
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Proposed Method

(a)Affordance Network   (b)Variable Agent Behavior Network   (c)Agent Behavior Network

A knowledge graph expressing the relationship between a noun (object) and the verb recalled from that noun

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Proposed Method

- ## Affordance Network
  - Extracting affordances from the relationship between verbs and nouns in sentences output by LLM
    - Verb-Object
    - Verb-Way

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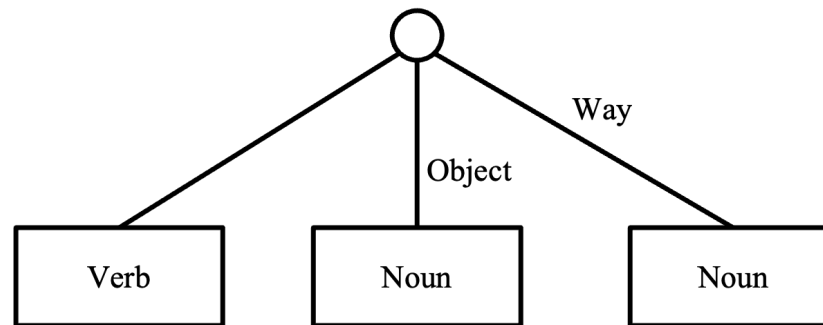
Affordance Network Construction Procedure
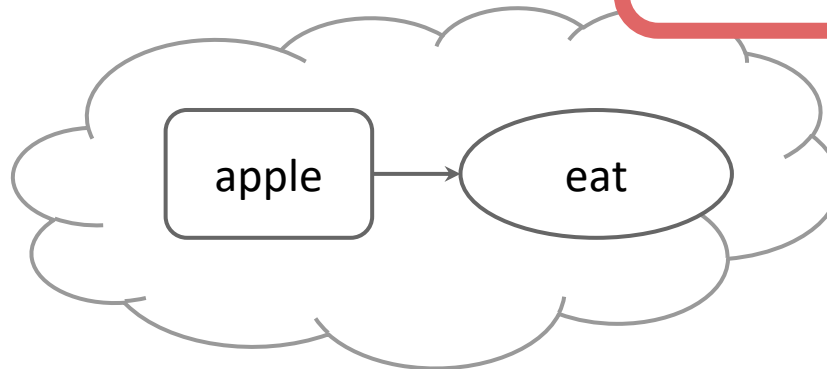
GPT-3

1. Sentence generation with GPT-3
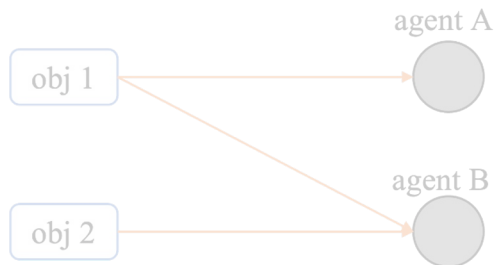
Q ： Story about an apple.   A ： He ate an apple.

2. Parsing with CoreNLP
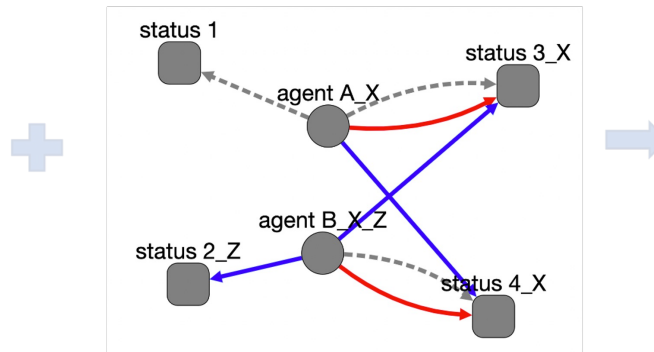3. Networking dependencies
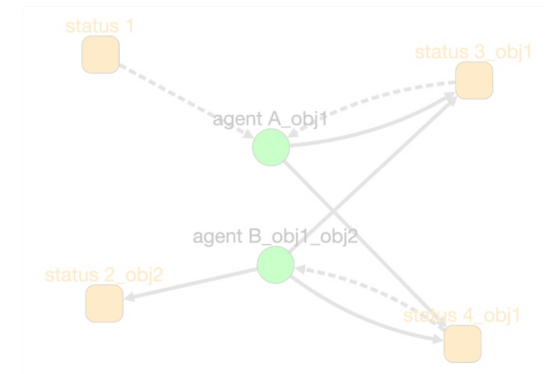
apple → eat

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Proposed Method

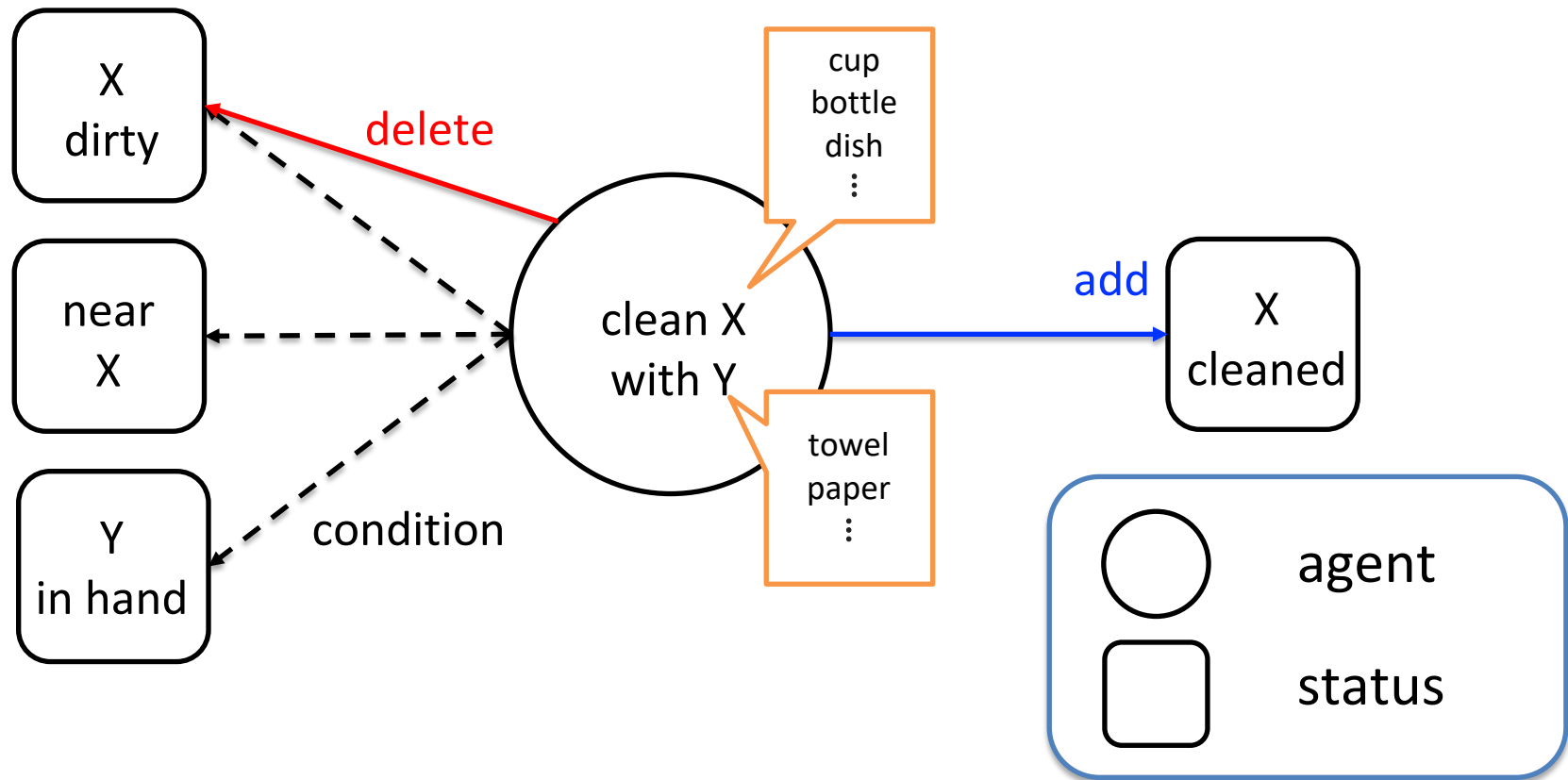(a)Affordance Network (b)Variable Agent Behavior Network (c)Agent Behavior Network

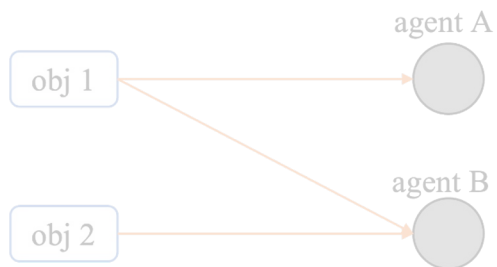ANA's network of agents and states with noun parts as variables

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Variable Agent Behavior Network

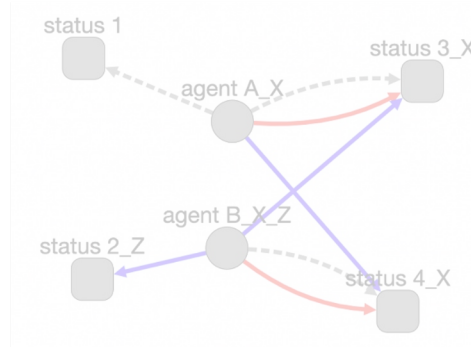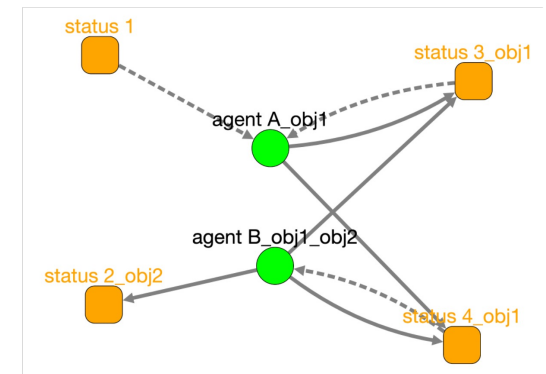- Variable ANA agents and statuses

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Proposed Method

(a)Affordance Network
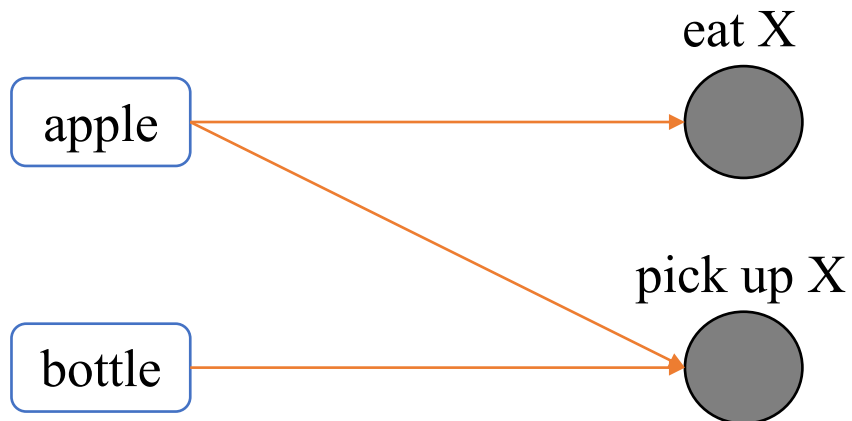
(b)Variable Agent Behavior Network

(c)Agent Behavior Network
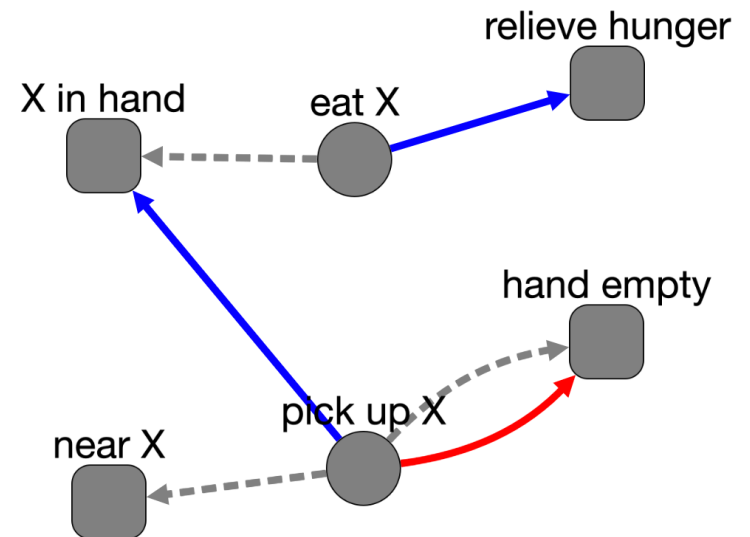
A network with a concrete object assigned to it

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Proposed Method

- ## Use of Affordances

Affordance Network

Variable Agent Behavior Network

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Proposed Method

- ## Use of Affordances

Agent Behavior Network

apple in hand   relieve hunger

eat apple

No useless agents like "eat bottle" are generated

hand empty

pick up bottle

near bottle   bottle in hand
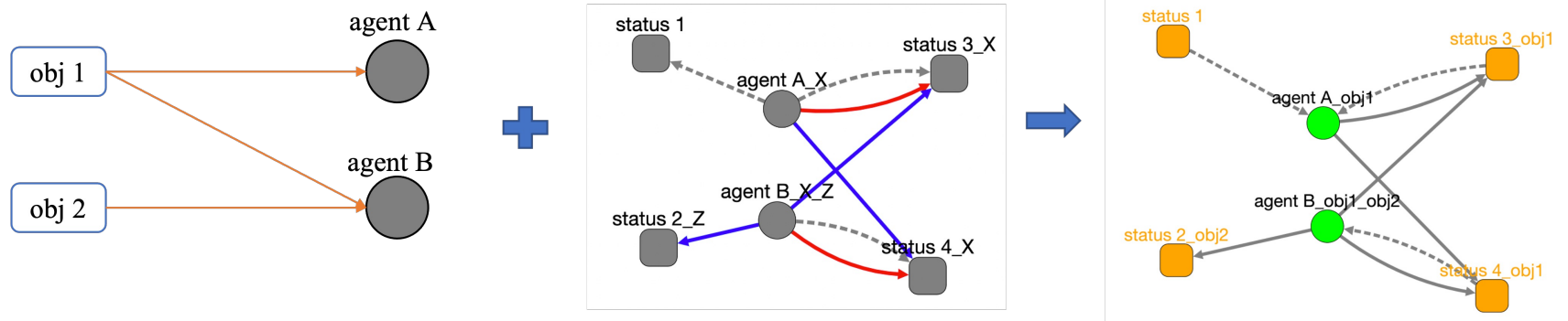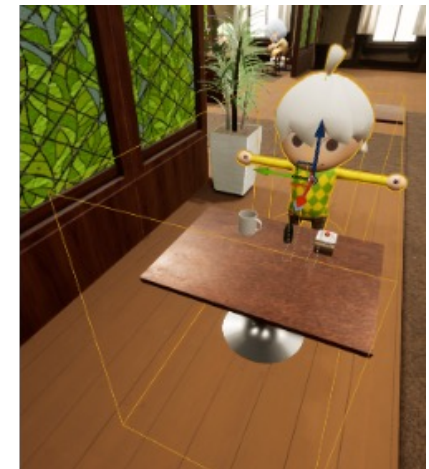
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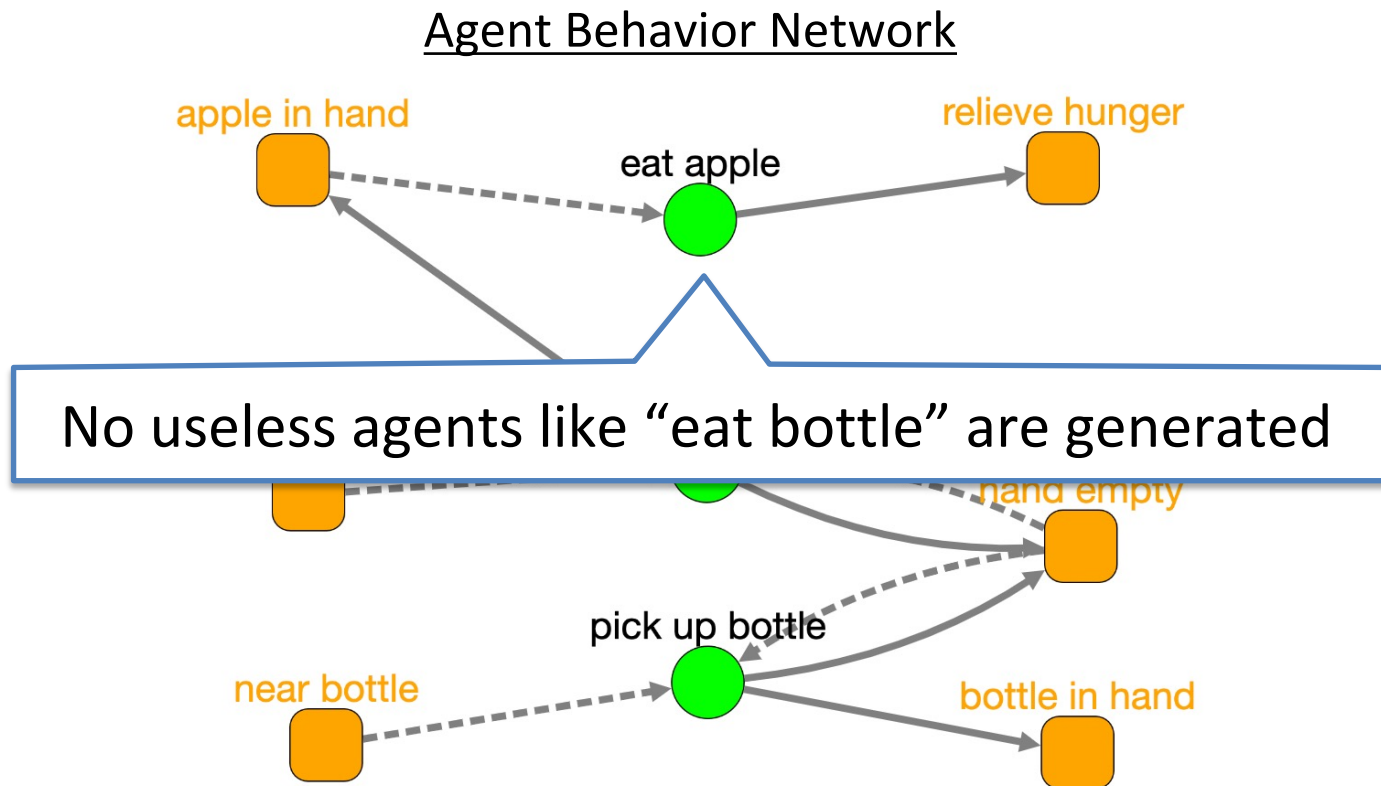
Experimental Objective

- To verify whether affordance can be applied to seek a sequence of actions to achieve goals efficiently
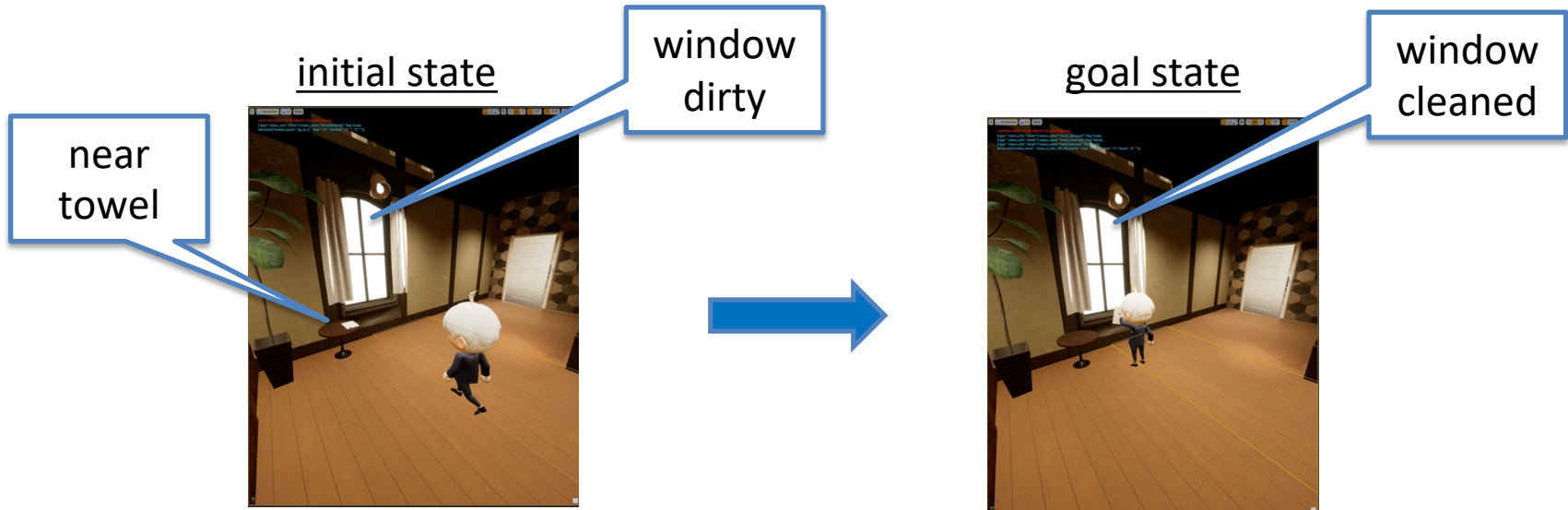
Experimental Environment

- Unreal Engine
  - Cafe 3D simulation

- Character
  - Actuators (execution of actions)
  - Sensors (acquisition of perceptual information)

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Experimental Scenario

- Nouns used
  - towel, window
- initial state and goal state

initial state

near towel

window dirty

goal state

window cleaned

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Experimental Scenario

- Action sequences required to achieve the goal

go to window

pick up towel

clean window with towel

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Data used in experiment

- Variable Agent
  – 35 kinds

- Affordance Network
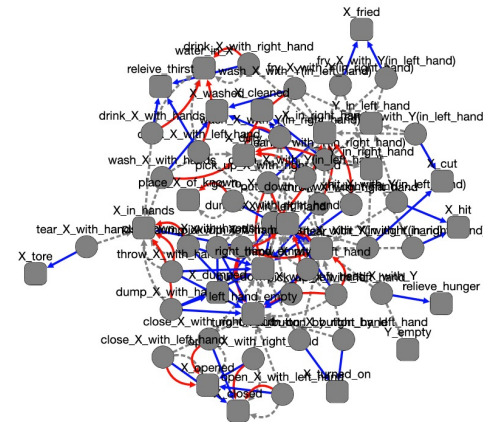
Data	個数
Verb Node	1,476
Noun Node	3,924
Verb-Object link	13,218
Verb-Way link	1,521

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Results of Evaluation

- ## Comparison of networks

With Affordances

agent: 16
link: 73

Without Affordances

agent: 70
link: 268

→ A more compact network could achieve the goal

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Results

- Video of UE in action (With Affordances)
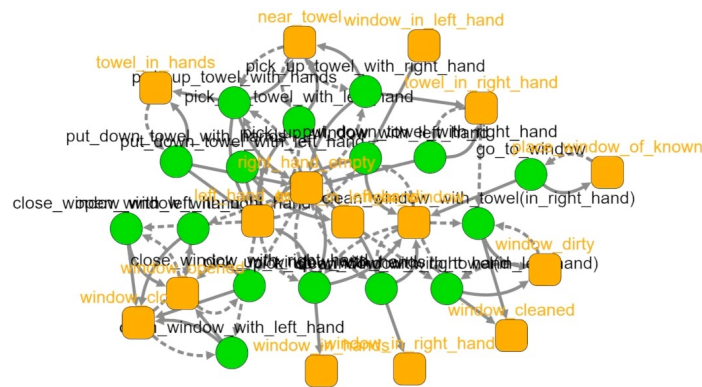
→ Properly executed actions as directed by the planner

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Conclusion and Future Work

- ## Conclusion:
  - The use of affordances in MAP was effective

- ## Future Work:
  - Use of affordances that take into account the attributes and positional relationships of objects -> Enables more situationally appropriate agent generation

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