

Embodied Agent-based Modeling

Integrating Large-Language Models within traditional ABMs

Dhruv Sharma, 17th October 2023

Objective

- Introduce the idea of Embodied agents
 - Difference with Computational Agents
- How can Large-Language Models be integrated for E-ABMs?
- Toy model example \implies New toolkit, challenges, applications

Plan

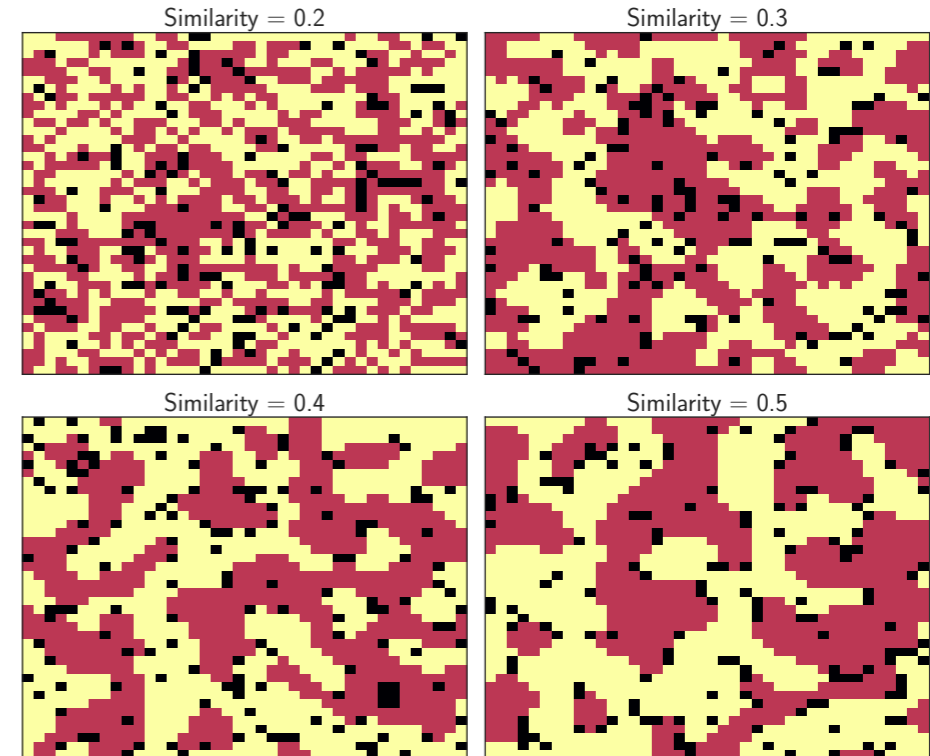
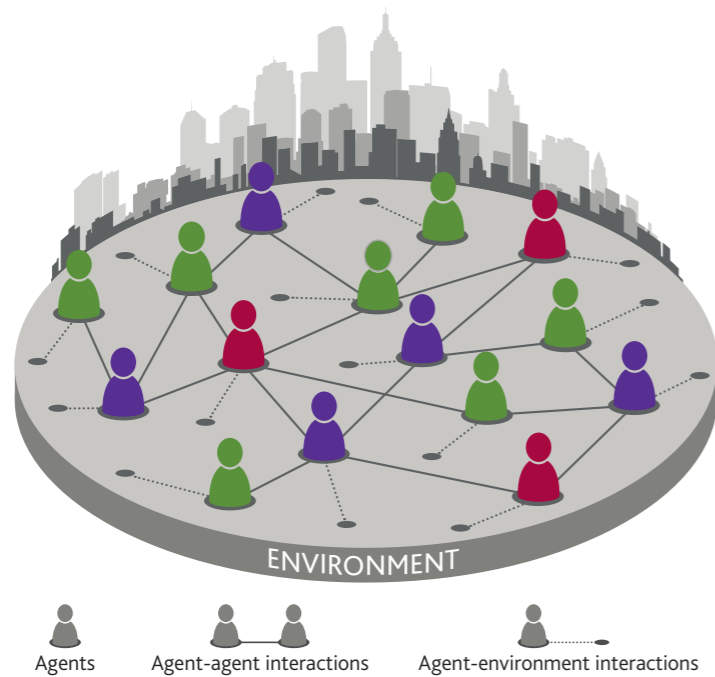
- Agent-based models and computational agents
- Embodied agents via Large-Language Models (LLMs)
- Example and preliminary results

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ABMs

- “Bottom-up” models by simulating each entity/agent.
- Agents follow behavioral rules as a function of environment and interactions.
- Aggregation can lead to non-trivial phenomena at the macro level.

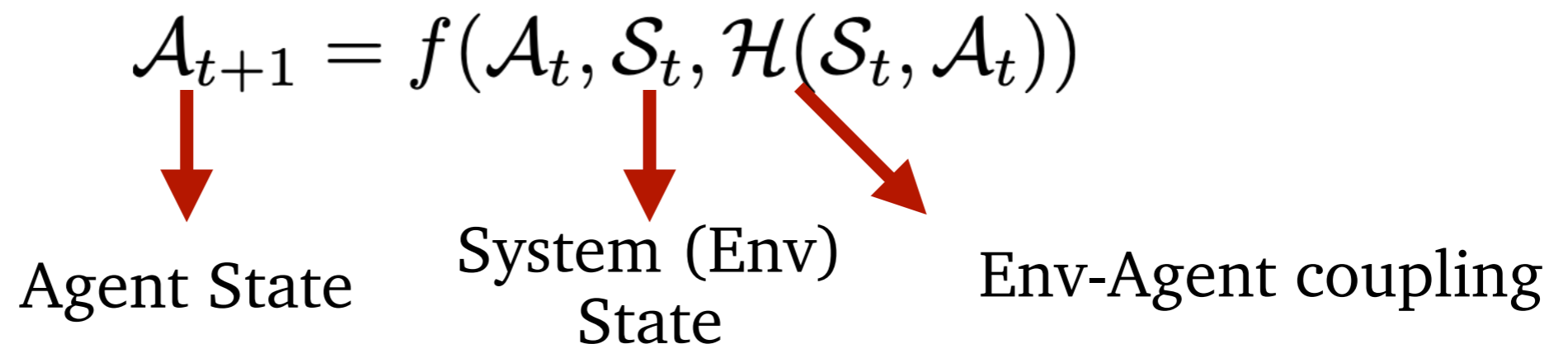


Networked model (from Turrell 2016)

Schelling Model of Segregation

Computational Agents

- Agents are “computational”
 - Behavioral rules are encoded as parametrized functions of (some) internal state

$$A_{t+1} = f(A_t, S_t, \mathcal{H}(S_t, A_t))$$


Agent State System (Env) State Env-Agent coupling

- Internal state is a simplified abstraction of a true “real-world” agent.

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- Example:
 - Opinions as Ising spins (or Potts spins)
 - Demand functions in 2-type ABMs of financial markets

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Embodied Agents

- Enhanced representation of a real-world behaviors.
- Definition and behavior not bounded by some functional representation.
- Can process unstructured external information.
- Example: Opinions “Generally prefer chocolate ice-cream, but would like vanilla today”

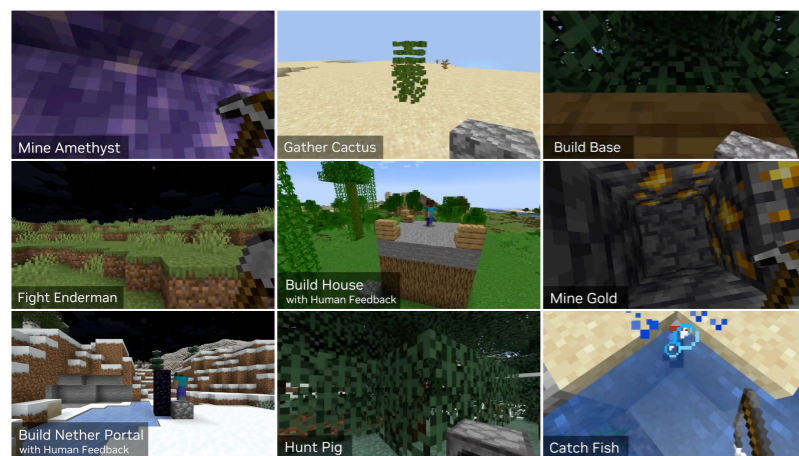
Embodied Agents - Via LLMs

- Large-language models pave the way

Voyager: An Open-Ended Embodied Agent with Large Language Models

Guanzhi Wang^{1,2}, Yuqi Xie³, Yunfan Jiang^{4*}, Ajay Mandlekar^{1*},
 Chaowei Xiao^{1,5}, Yuke Zhu^{1,3}, Linxi "Jim" Fan^{1*}, Anima Anandkumar^{1,2†}
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arXiv PDF Code Tweet MineDojo



Single agent exploring and building in Minecraft

Generative Agents: Interactive Simulacra of Human Behavior

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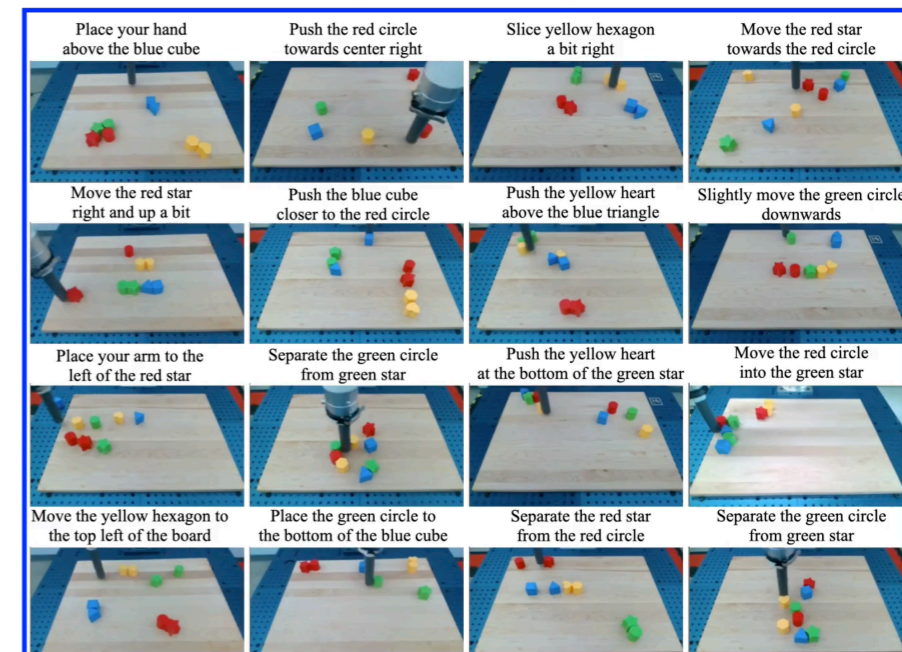
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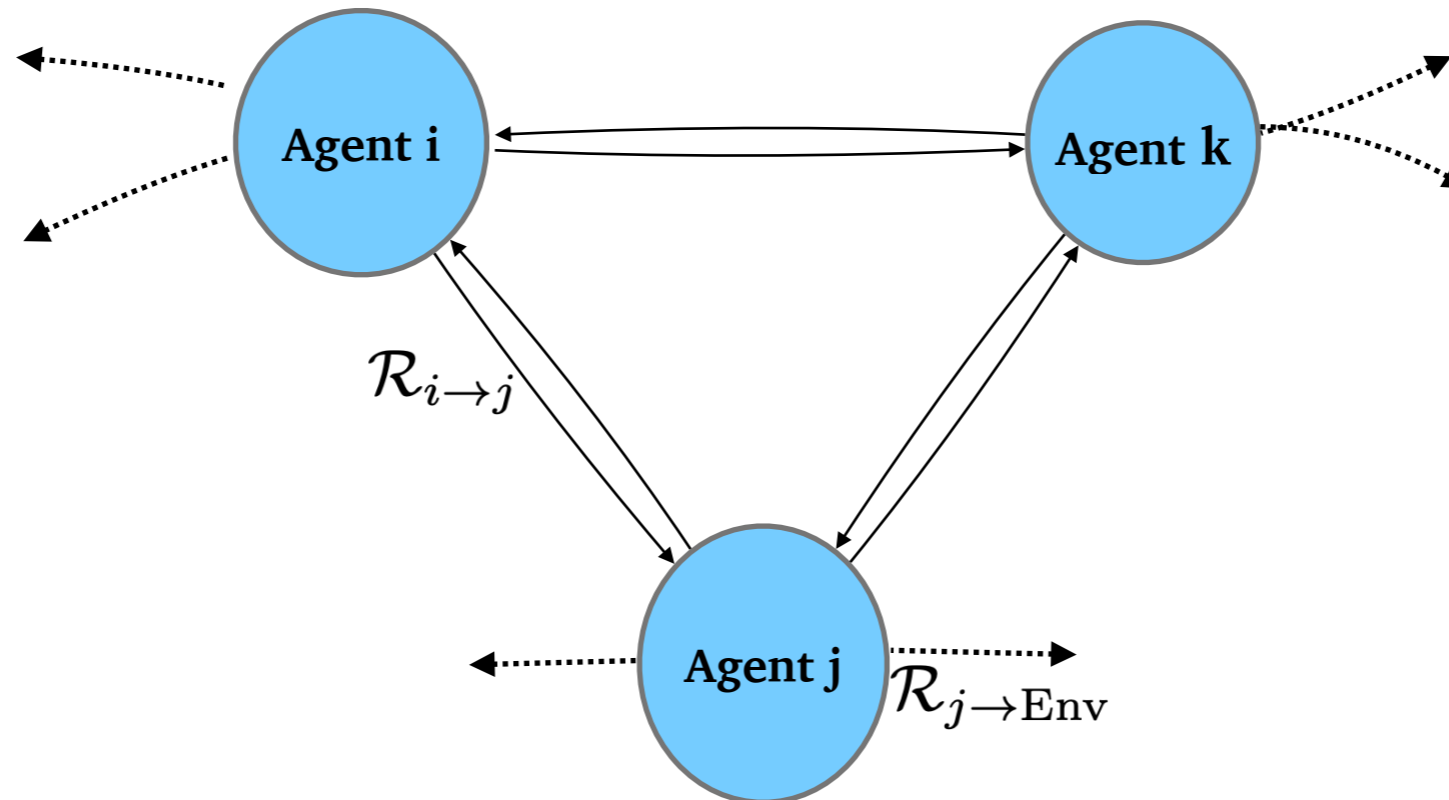
Figure 1: Generative agents are believable simulacra of human behavior for interactive applications. In this work, we demonstrate generative agents by populating a sandbox environment, reminiscent of The Sims, with twenty-five agents. Users can observe and intervene as agents plan their days, share news, form relationships, and coordinate group activities.

Simulate real-world interactions in a small neighborhood.



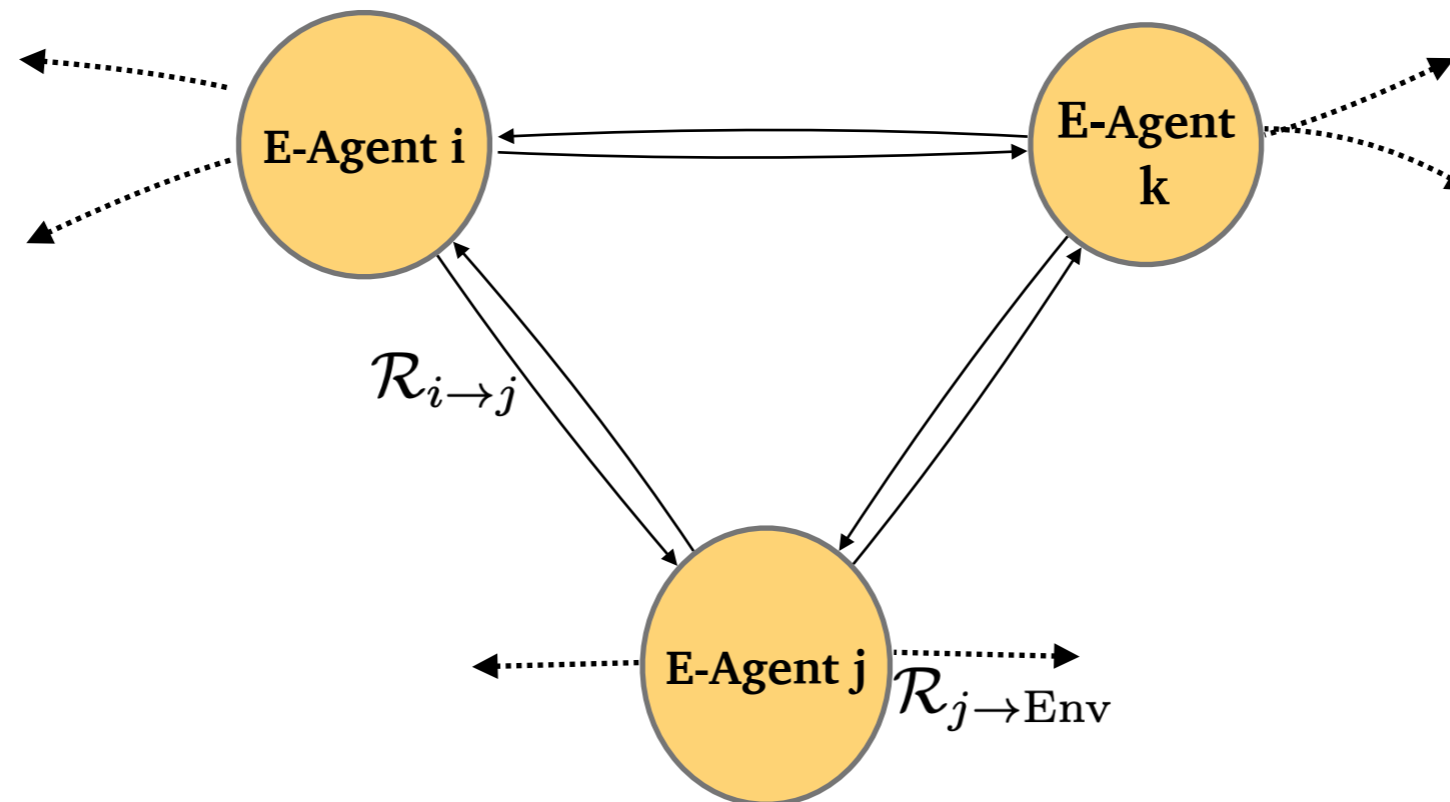
Robotic arm learns a world representation through visual and textual commands

Computational vs Embodied Agents



- For Computational Agent j:
 - Define internal state - opinion vector, propensity to change opinions,
 - Environmental Interactions - nearest neighbors via graph topology, coupling with other agents
- Overall dynamics defined on the “computational” states of the agents.

Computational vs Embodied Agents



- Each embodied agent has:
 - An internal LLM, a memory store, a “persona”
 - Describe internal state via “prompt”: text-based input to produce desired outcome from LLMs
 - Environmental Interactions - mediated by messages passed from one agent to the other.
- Overall dynamics is turn based. Each agent speaks/acts when its their turn.

Prompts

- Text-based description of desired output from LLM
- Example: generate agent descriptions, based on persona.

I want to create descriptions for different types of agent. Based on their personas, you should add the following information for the agent:

1. Educational status
2. Political beliefs on the following topics: Abortion rights and Gun rights

```
Persona(  
    name='Daniel Zhang',  
    age=70,  
    traits='extrovert, closed-minded,  
conservative, all opinions are weakly held, is  
susceptible to change,  
technology',  
    status='employed'  
)
```

Stephen Watson, a 24-year-old employed individual, is an extroverted and open-minded person. However, when it comes to politics, Stephen tends to be fickle-minded and changes their stance frequently. Their conservative beliefs shape their political views on various topics.

Abortion rights: On the matter of abortion rights, Stephen may lean towards a pro-life perspective advocating for restrictions or limitations on access to abortion services. They might prioritize the sanctity of life from conception onwards.

Gun rights: In terms of gun rights, Stephen likely supports the idea that individuals have the constitutional right to bear arms. They might align with policies that promote minimal government intervention in firearm ownership and advocate for responsible gun ownership as a fundamental right upheld by the Second Amendment.

Plan

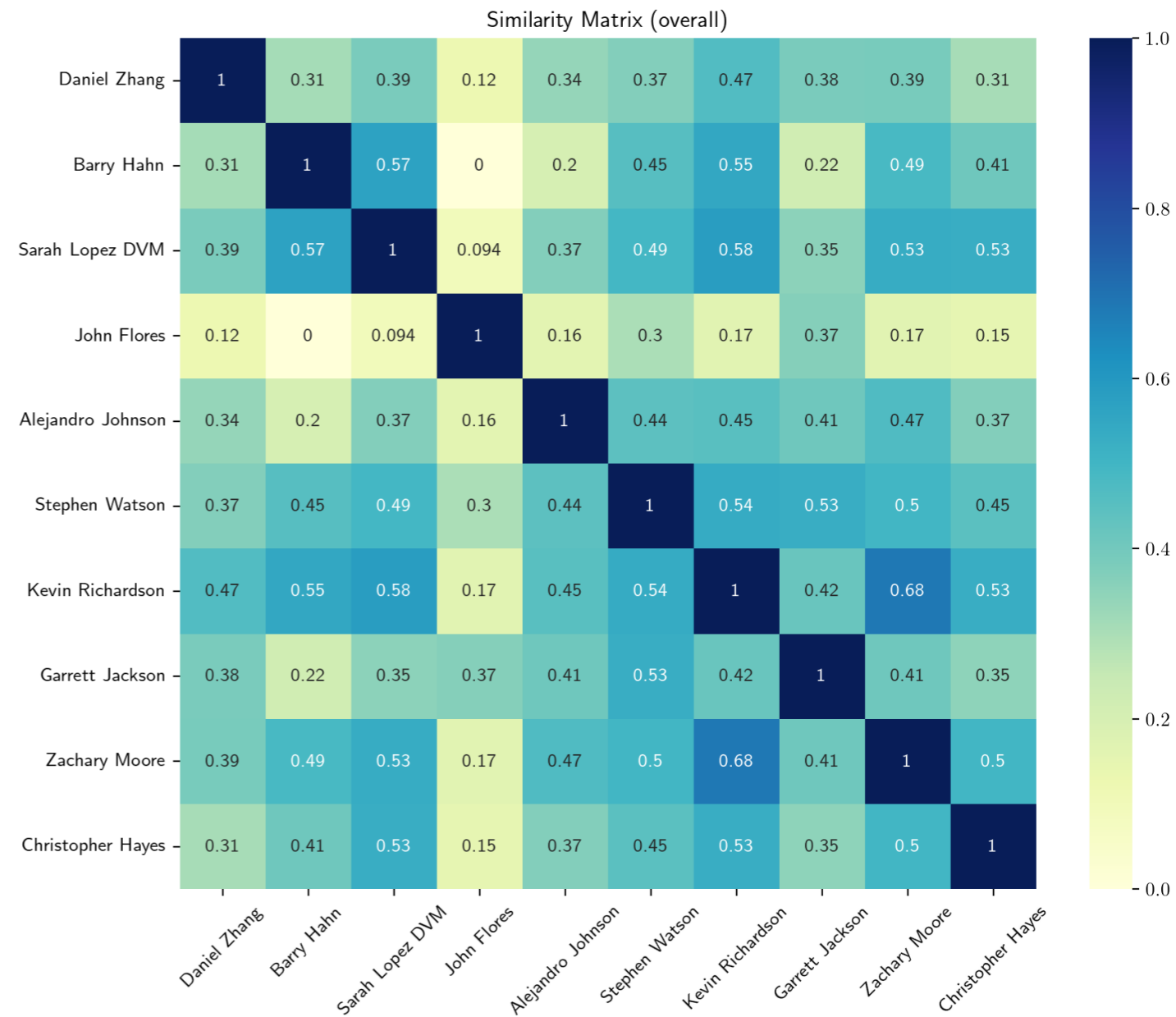
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Example - Opinion Dynamics

- Embodied agents with a mediator on a small-world network.
- Turn based simulation. Agents can respond to each other.
- Each agent has rudimentary memory.

Results

- Large dispersion in opinions overall. Clear separation between certain agents.



Results

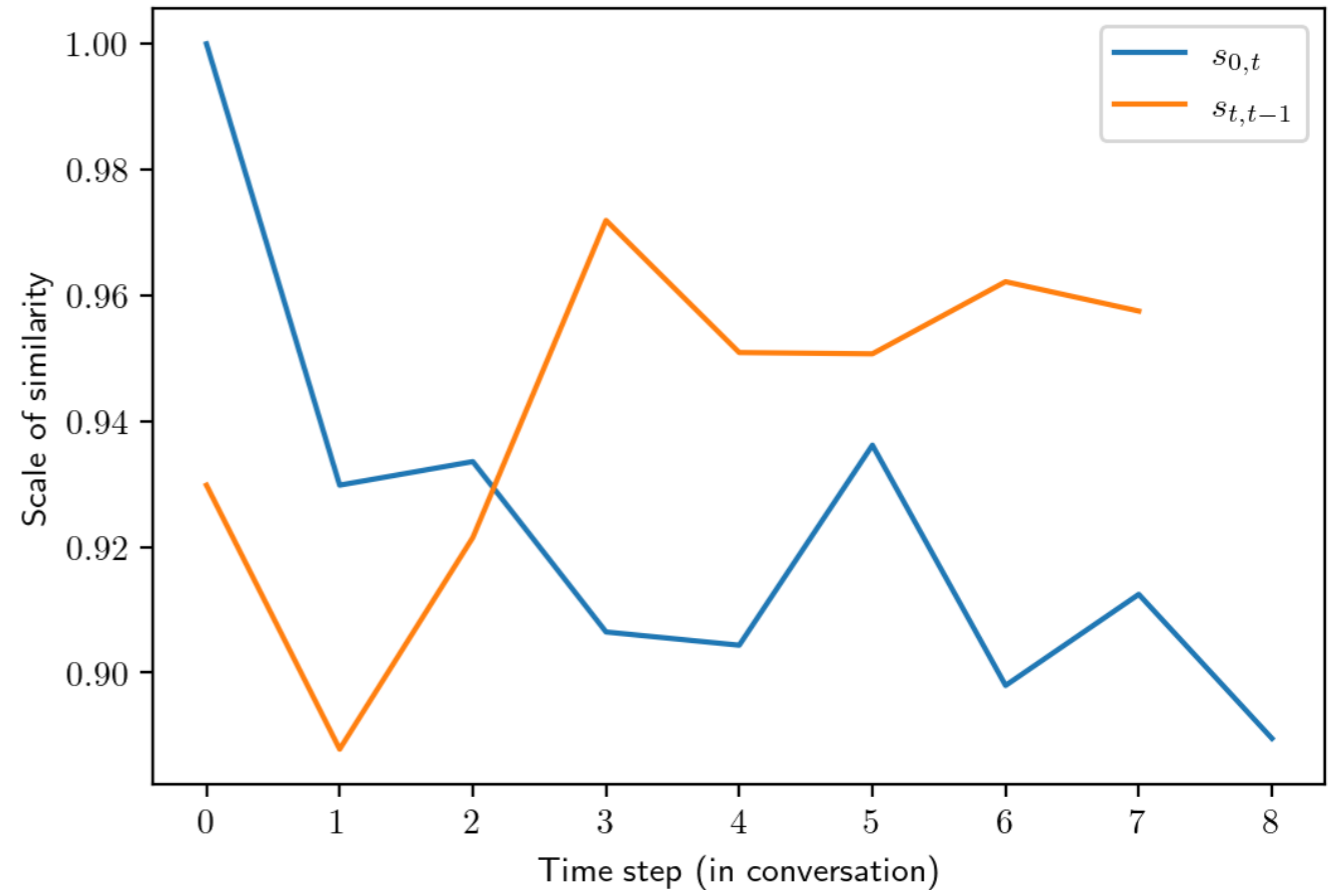
- Initial persona has direct impact on changing opinions.

```

Persona(
  name='Sarah Lopez DVM',
  age=73,
  traits='extrovert, open-minded,
independent, all opinions are weakly held, is
susceptible to change, politics',
  status='unemployed'
)

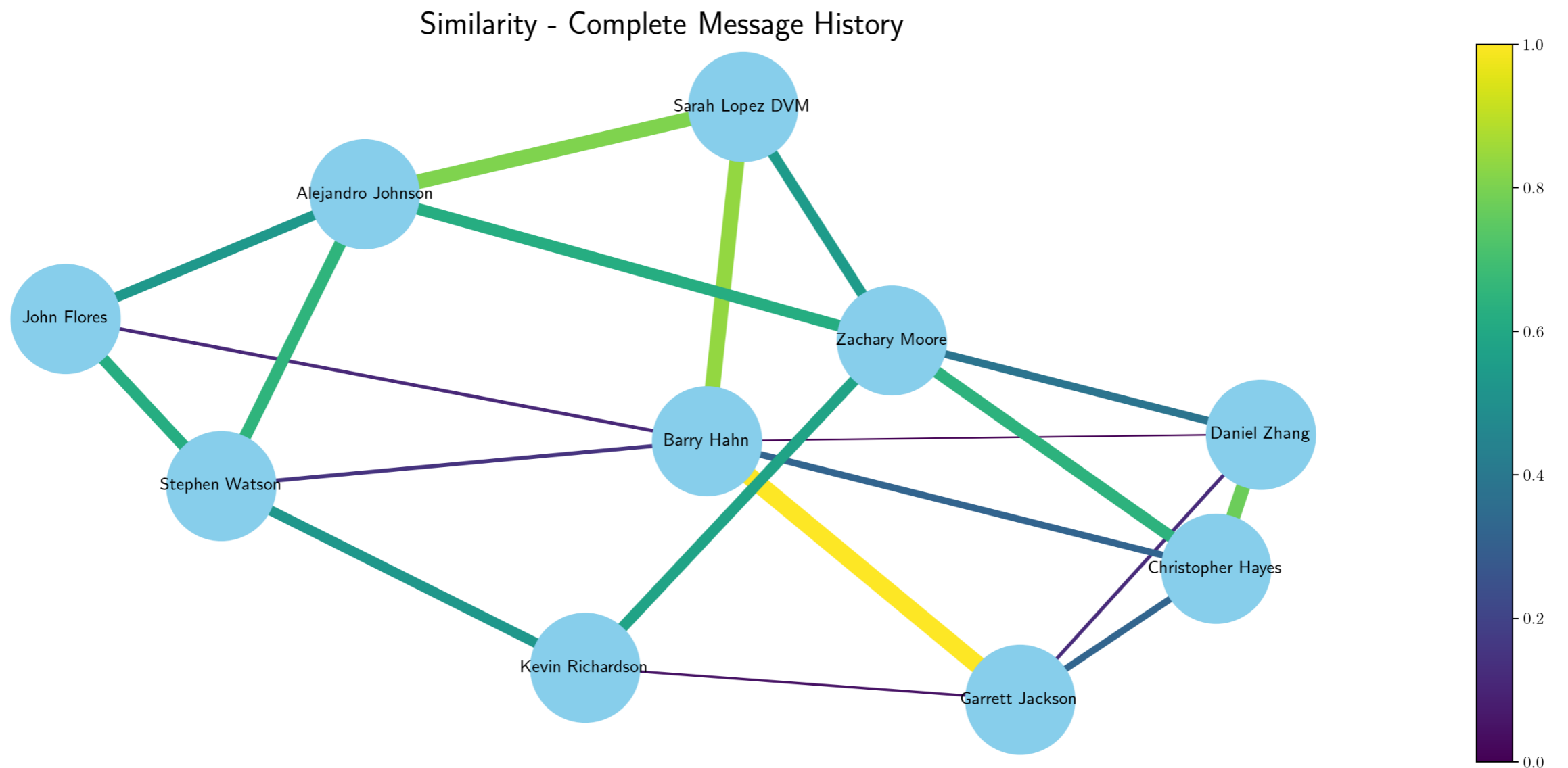
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Change in opinion similarity - Agent: Sarah Lopez DVM



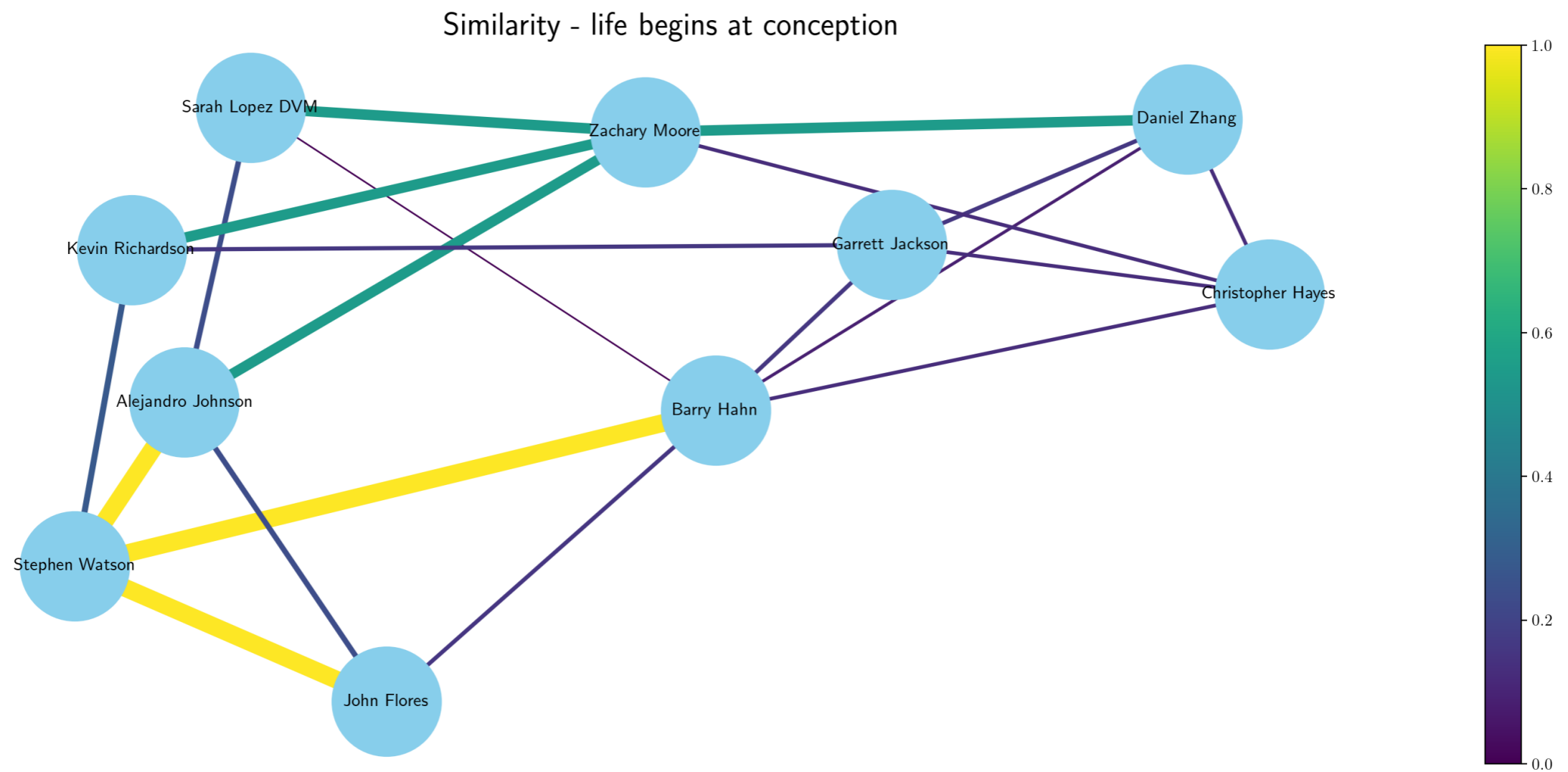
Results

- Similarity Network is different based on question asked



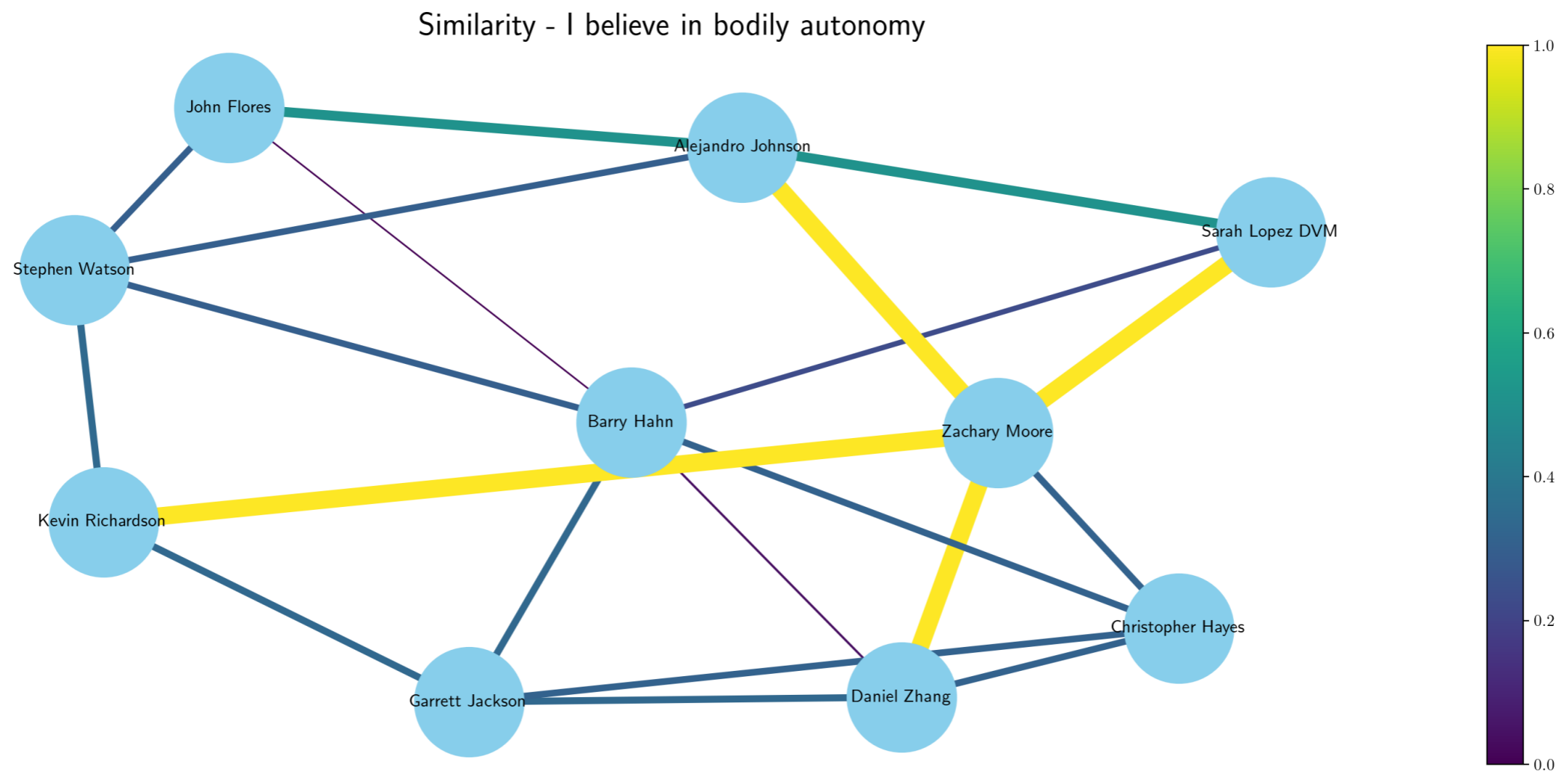
Results

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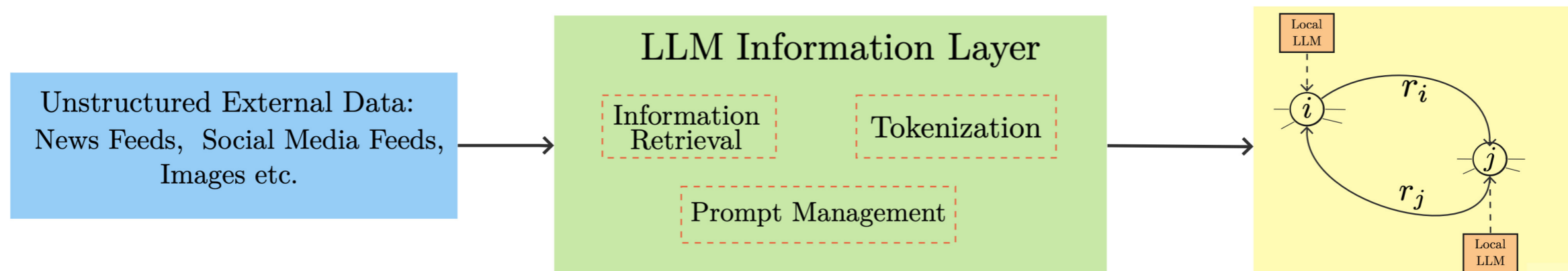
Results

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Open questions, Next Steps

- Introduced the notion of embodied agents through the use of LLMs
- Integrate external information such as news feeds, images.
- Scale: Number of agents in simulations. Scale the extent of memory (add true cognitive architecture) \implies Local LLMs to reduce cost
- Challenge in prompting and tracking experiments \implies impact of LLM parameters on simulation results
- Compare with existing models (transform opinions back to discrete space)
- Alternative to existing methods for AI Alignment?



Homo Economicus

Embodied Agent

Computational Agent



Single agent, too many assumptions, not realistic. tractable.

Reasonable middle. Realism, believable proxy of human behavior

Simple agent, scales well. Behavioral rules are hand-crafted.

