The Effect of Network Regularity on Coordination with Limited Rationality

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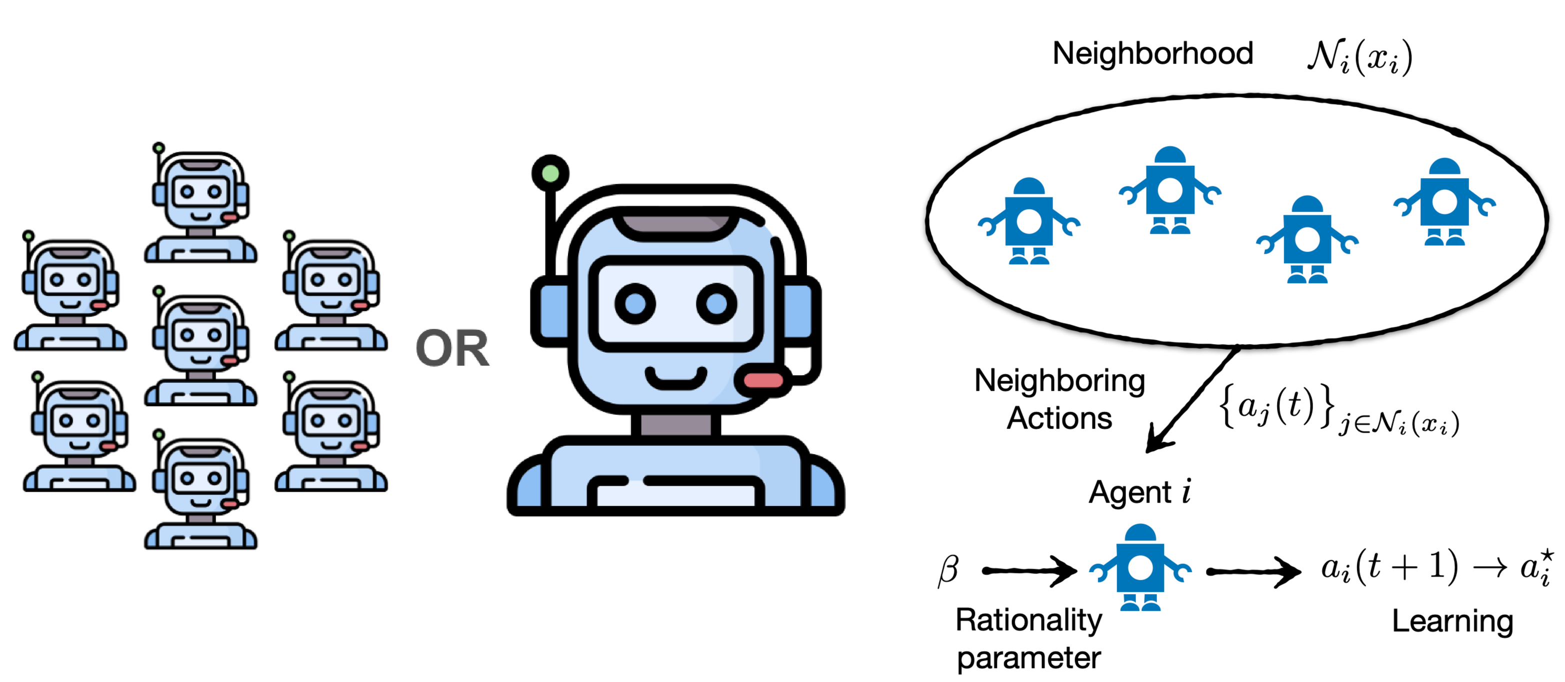
Motivation

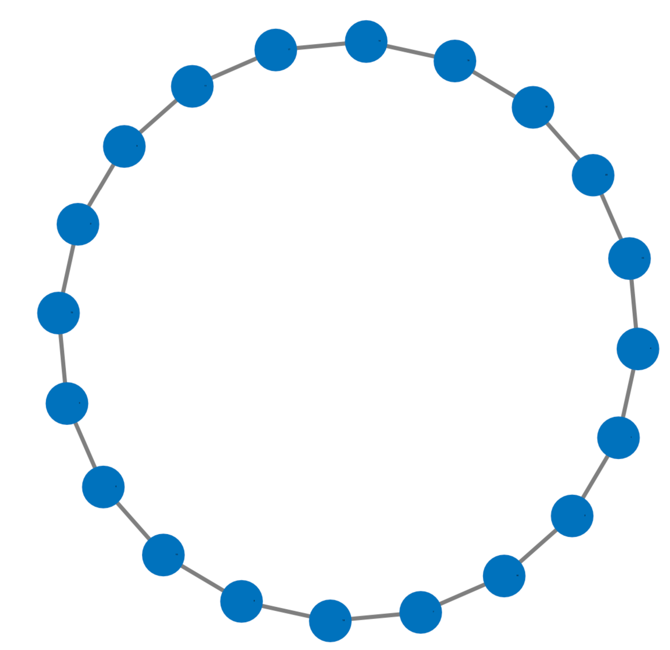


- **Multiple robots** can accomplish tasks that a single robot cannot.
- In real-world scenarios, robots operate with **bounded rationality**, interrupting effective coordination.
- How can we **enhance coordination** in networks with limited rationality?

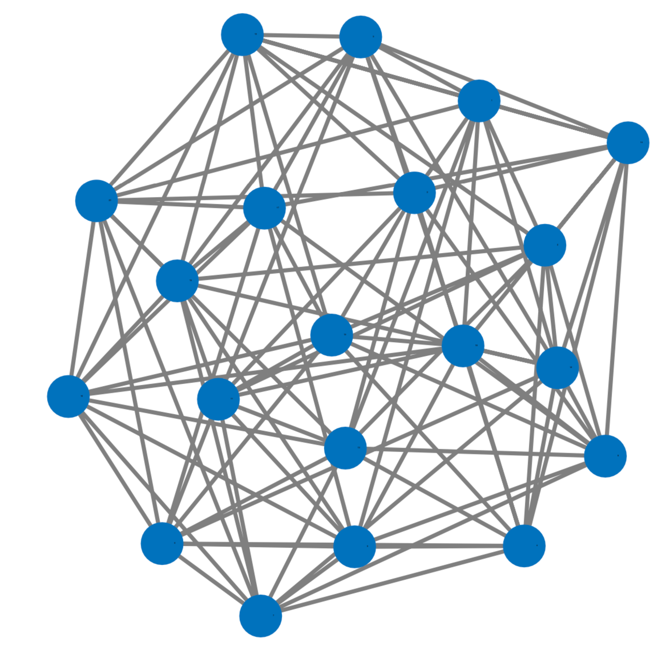
Background

Prior Research Findings:

- Among networks with an equal number of agents, those with **more connections** coordinate **more effectively**.
- Enhanced connectivity can **compensate** for agents' **limited rationality**.



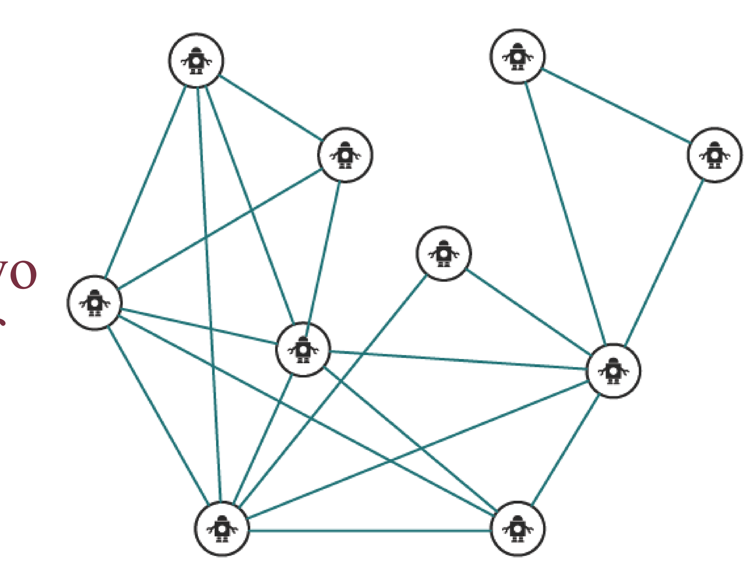
20 agents with less connections



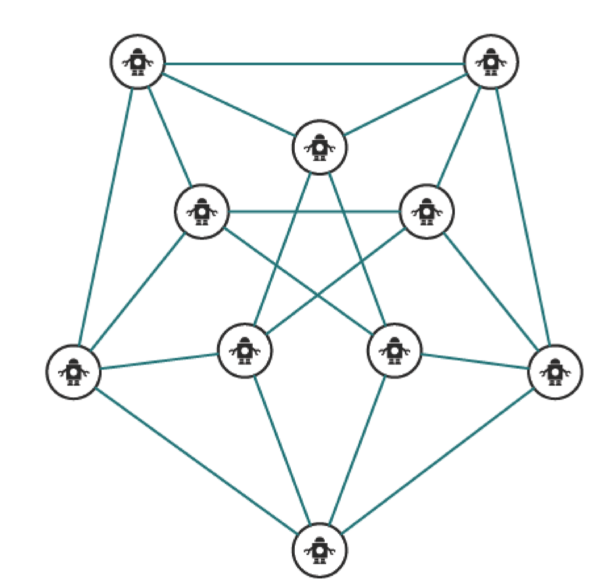
20 agents with more connections

Key Question:

- How do the **network structures** influence agents' coordination if two networks have the same number of agents and connections?
- This study examines the impact of **network regularity** on agents' coordination.



Irregular network

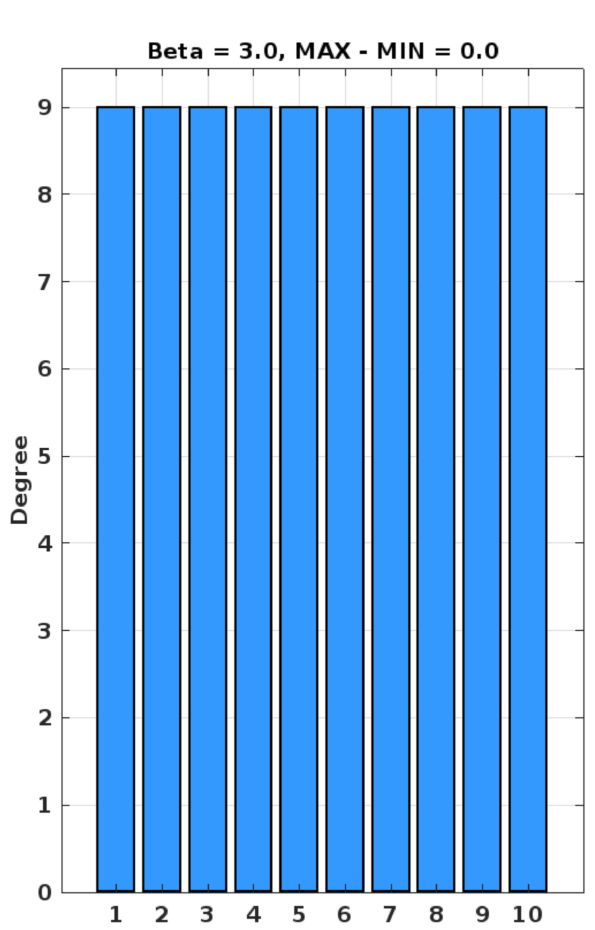


Regular network

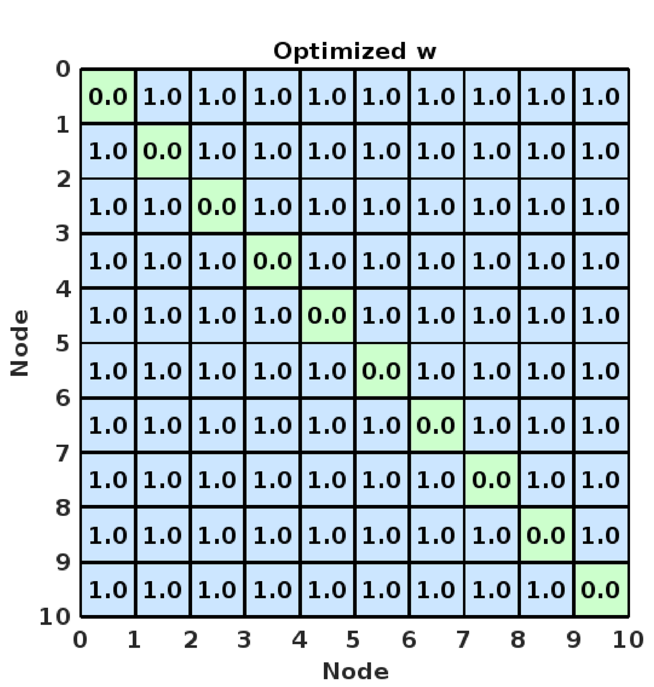
Methods

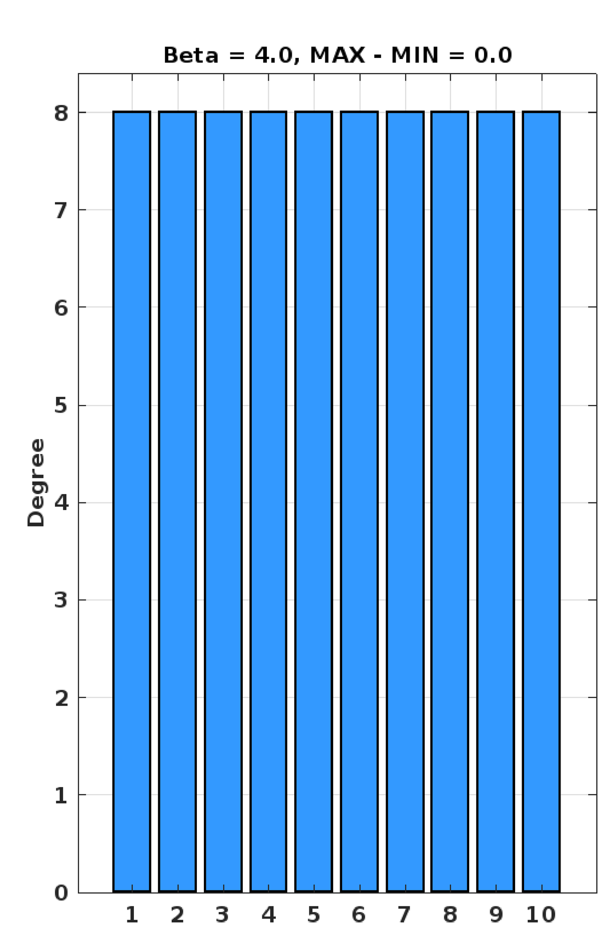
- Formulated an **optimization problem** in MATLAB subject to constraints ensuring a valid undirected graph (symmetry, zero diagonal).
- Employed MATLAB's built-in solver ***fmincon*** to minimize the objective function capturing overall coordination.
- Adjusted the adjacency matrices systematically to investigate the resulting graph structures, focusing on **degree distributions**.

Results / Future Directions

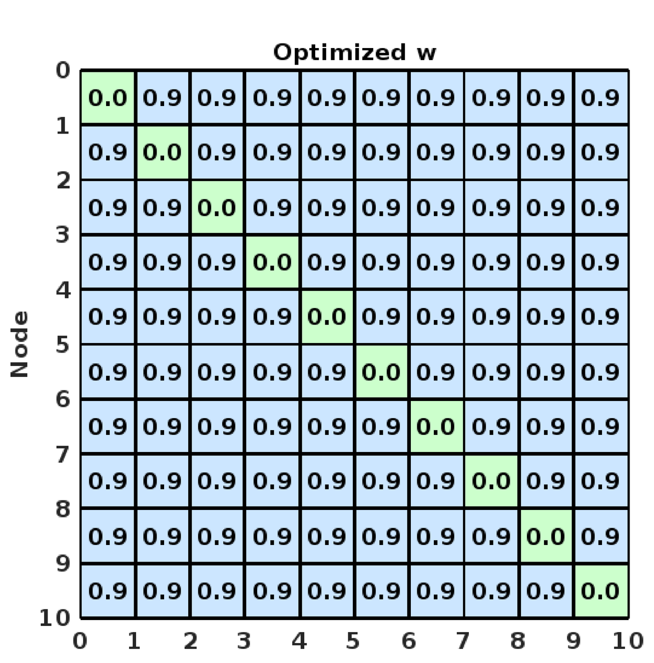


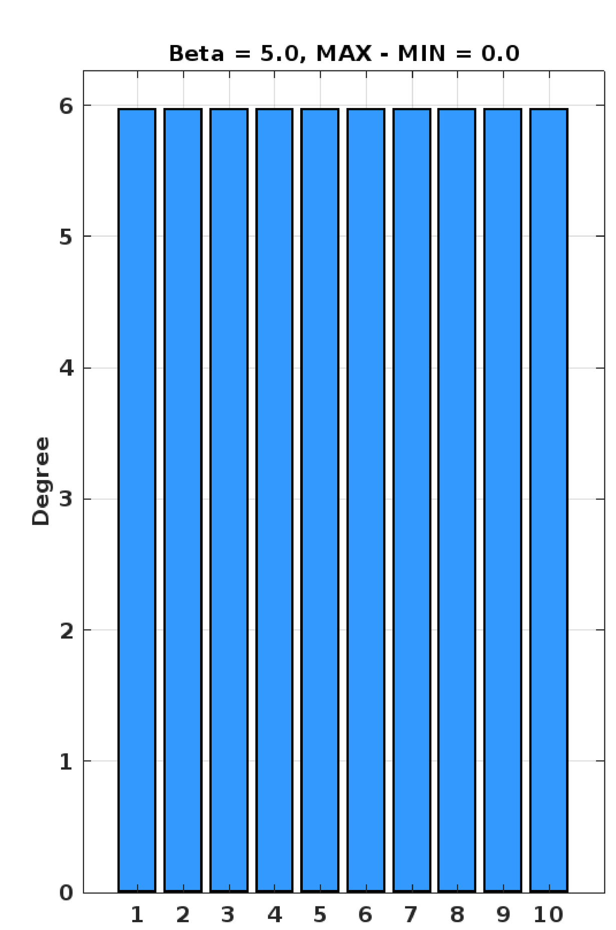
1. β = 3



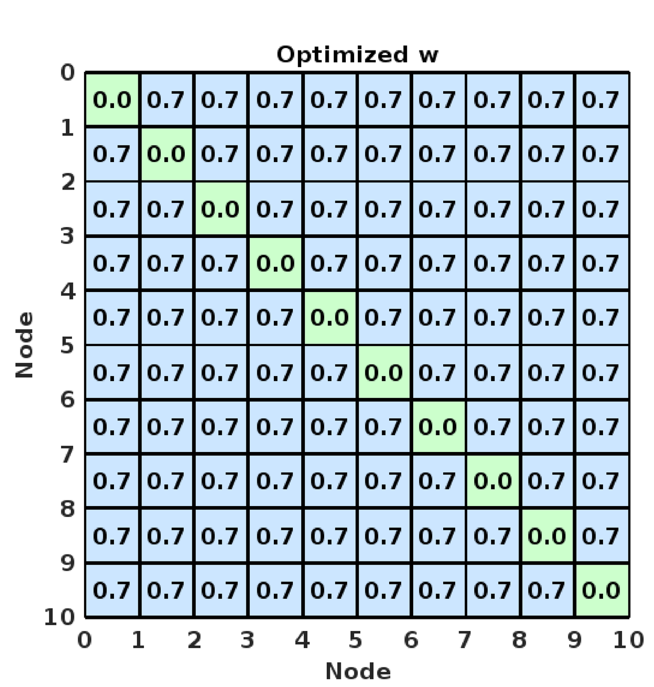


2. β = 4





3. β = 5



$$\min_{w\in[0,1]^{N\times N}} \sum_{a\in\{0,1\}^N} \exp\left(\beta\left(\tfrac{1}{2}\, a^\mathsf{T} w\, a \;-\; \tfrac{\theta}{N}\, \mathbf{1}^\mathsf{T} w\, a\right)\right),$$

$$\text{subject to} \quad \operatorname{trace}(w) = 0, \quad w = w^\mathsf{T}.$$

Objective Function

- **Optimized adjacency matrices** for 10-node networks in MATLAB with parameters: Edge = 10, θ (Difficulty) = 7, β (Rationality) = 3, 4, 5.
- Matrix entries were **rounded** to one decimal place.
- **The optimizations** consistently produce **regular graphs** where every node has the same degree, suggesting that agents' coordination is most effective in a regular graph, compensating for bounded rationality.
- **Future work** will investigate scenarios with heterogeneous agent rationality and noise in communication and task perception.

References

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