Reward-Sharing Relational Networks in Multi-Agent Reinforcement Learning as a Framework for Emergent Behavior

AAMAS 2021, Adaptive and Learning Agents Workshop

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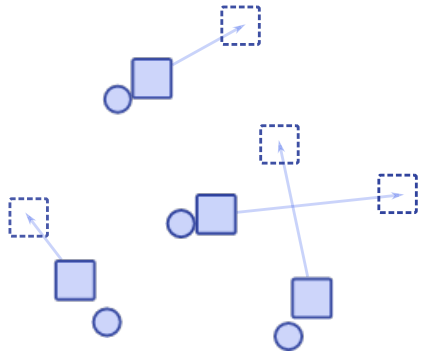
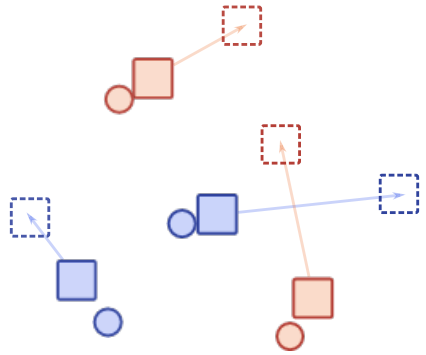
Collaborative vs. Team-based vs. Self-interested MARL

- **Example:** Moving objects from point A to B

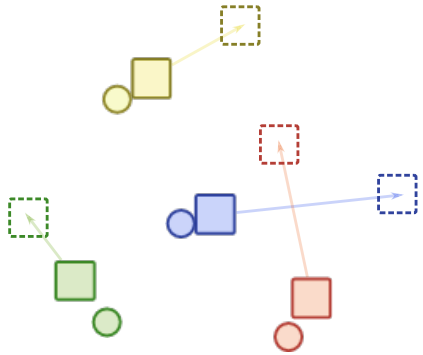
Collaborative (single task)
(single global reward function)



Multiple teams
(single global reward function)



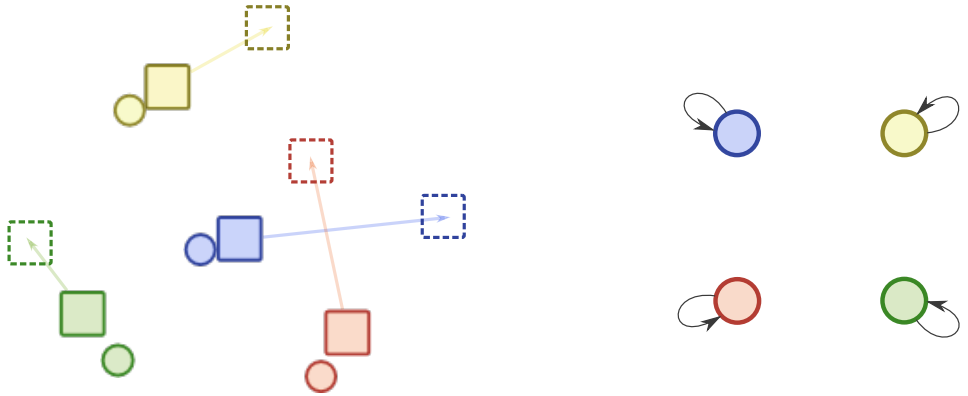
Self-interested
(Single reward function per agent)



What about more complex social networks?

Explicit implementation of networks for multi-agent RL systems

- Building Reward Sharing Relational Network (RSRN) which determines who 'cares' about whom
- If agent i is linked to agent j it means it receives reward according to agent j's individual reward



Explicit implementation of networks for multi-agent RL systems

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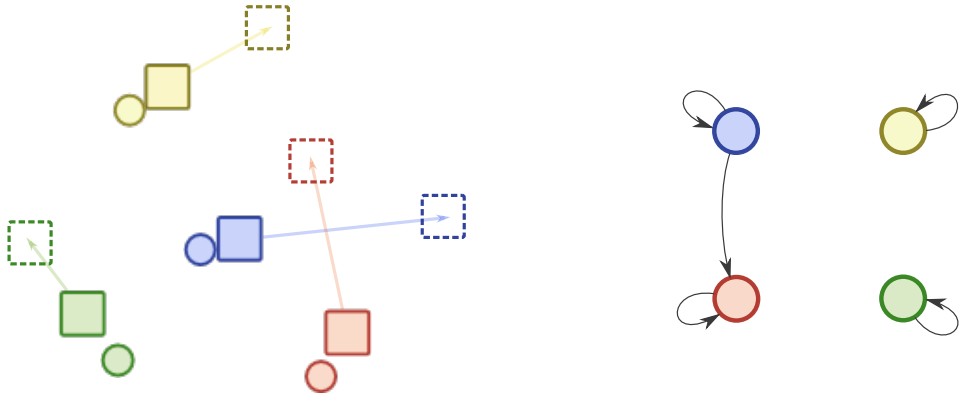


Reward Sharing Relational Network (RSRN)

- RSRN can be fully defined by the adjacency matrix $W_{\mathcal{G}}$

$$W_{\mathcal{G}} = \begin{pmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,N} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N,1} & w_{N,2} & \cdots & w_{N,N} \end{pmatrix}$$

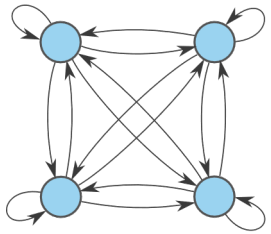
Agent 1's social orientation

Agent 2's social orientation

Agent N's social orientation

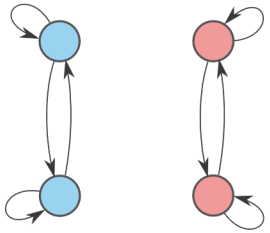
- Weights could be any real number in general (including negative values)

Collaborative vs. Team-based vs. Self-interested vs. Complex MARL



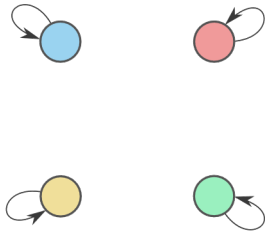
Collaborative

(single global reward function)



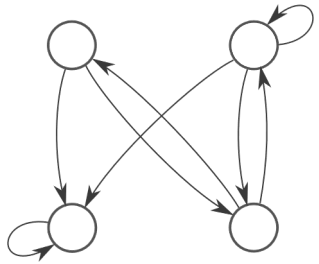
Multiple teams

(single global reward function)



Self-interested

(Single reward function per agent)



Complex Social Network

[2] Baker, Bowen, et al. "Emergent tool use from multi-agent autocurricula." arXiv preprint arXiv:1909.07528 (2019)

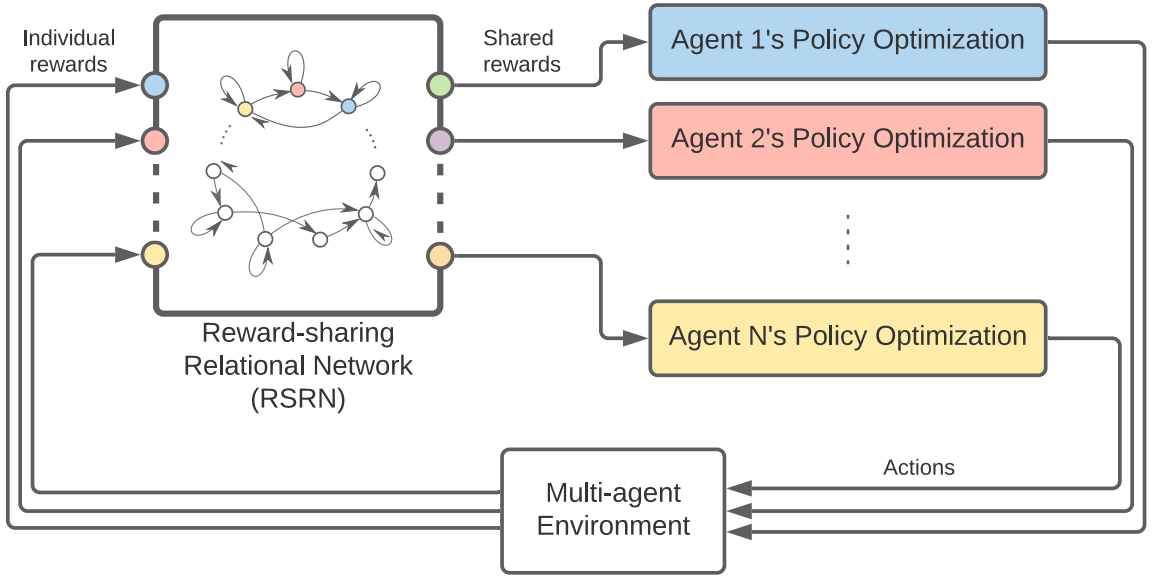
Building composite rewards by scalarization

- Agents try to maximize their shared return $\bar{R}_i$ by accumulating the discounted shared rewards:

$$\bar{R}_i = \mathbb{E}\left(\sum_{k=0}^{T} \gamma^k \bar{r}_{i,k}\right)$$

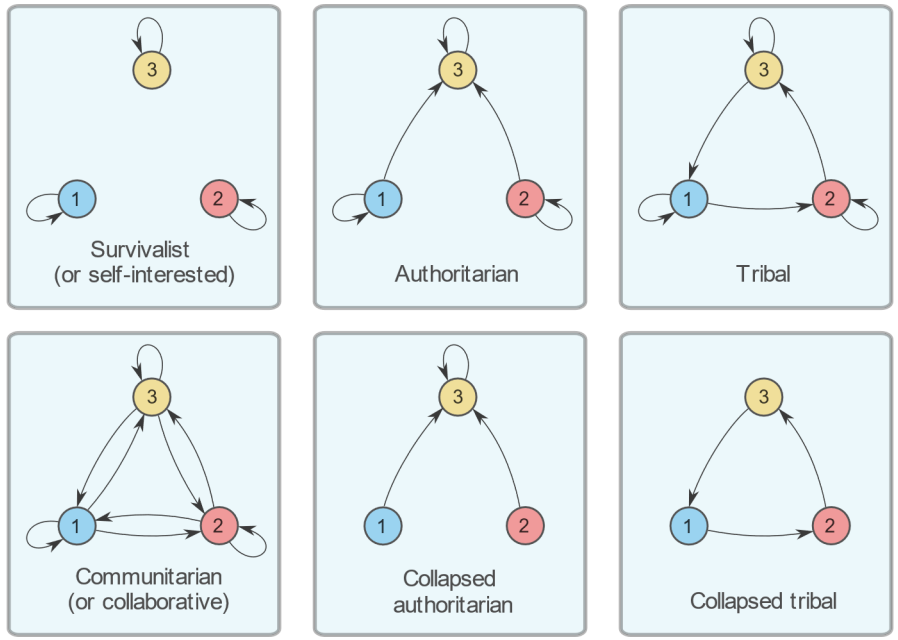
- Reward scalarization using Weighted Product Model (WPM)

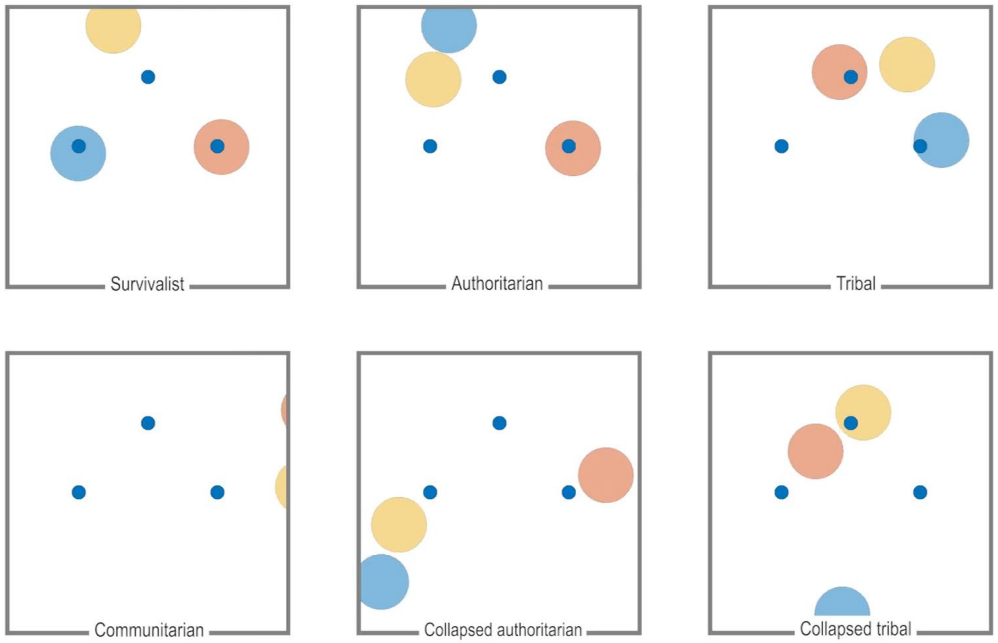
$$\bar{r}_i = \prod_{j=1}^{N} r_j^{w_{i,j}}$$



Evaluating RSRN using a 3-agent MARL environment

- **Scenario:** 3 agents try to get to the closest landmark as fast as possible (agent 3 is slower than others)

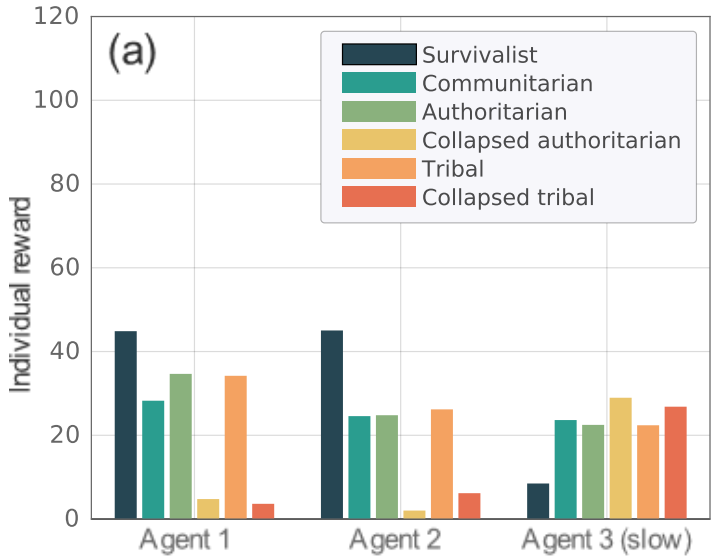


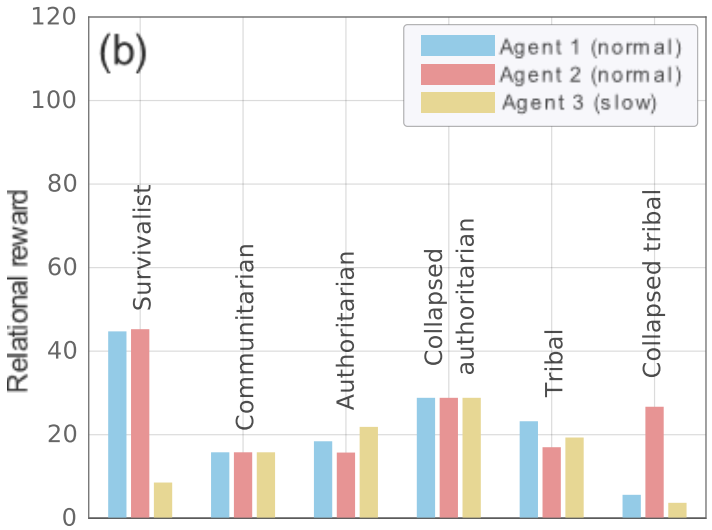


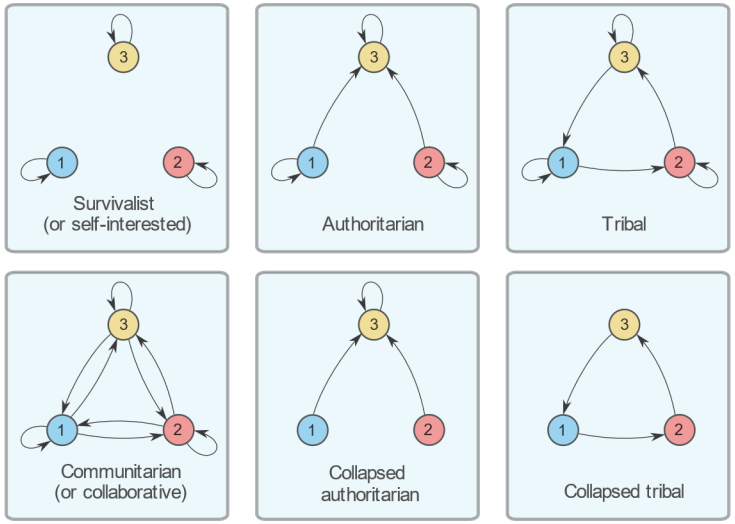
Video is available at sites.google.com/view/marl-rsrn

Balancing agent performances towards RSRN

- Training agents using MADDPG[1] for 500K episodes
- We can measure individual performance of the trained agents using their individual rewards (averaged over 5K test episodes)







[1] Lowe, Ryan, et al. "Multi-agent actor-critic for mixed cooperative-competitive environments." arXiv preprint arXiv:1706.02275 (2017).

Conclusions

- RSRN can effectively balance A MARL system towards any arbitrary network
- Scalability to large number of agents
- Policy Intractability for agents with several out-going connections
  - Can be addressed by credit assignment approaches
  - Many real-social networks are sparse (small number of out-going connections)
  - We expect to have a sparse RSRN for large scale systems
- Choosing the right scalarization function

Thank you!

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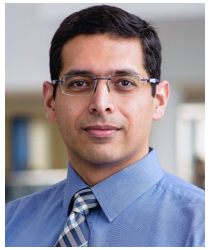

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