

A Appendix

A.1 Environment Scenarios

A.1.1 Cooperative Navigation (CN)

In the CN settings of the MPE environment, agents need to work collaboratively to ensure that every landmark is covered by at least one agent. Here are the various configurations we've designed for this environment, each with a unique agent distribution:

- **CN(1):** This scenario features 9 agents, grouped into three categories, with a distribution of [3, 3, 3]. The agents aim to ensure that each of the 3 unique landmarks is approached by at least one agent.
- **CN(2):** This setup has 12 agents, also divided into three categories, with the distribution being [3, 4, 5]. Similar to CN(1), the agents are tasked with navigating and coordinating to cover all three landmarks.
- **CN(3):** This is the advanced challenge in the CN scenarios, including 15 agents. They are evenly grouped into three categories, each having a distribution of [5, 5, 5]. The primary task remains the same: ensuring effective coverage of the three landmarks by the agents.

A.1.2 Predator and Prey (PP)

Inspired by the "Blind Particle Spread" environment, the Predator and Prey (PP) scenario requires two types of agents to work closely together to track specific targets. Unlike the typical PP scenarios, agents in this setting face a unique challenge: they cannot directly identify their own type or that of other agents.

Within this environment, agents have knowledge of their position, speed, and the relative positions of moving targets. However, to heighten the complexity of the game, we've intentionally diminished the agents' perceptual capabilities by providing them with slightly inaccurate information, making it challenging for them to discern the exact locations of distant targets. Agents earn rewards based on how close they get to the correct targets, and they face penalties for any collisions with other agents.

- **PP(1):** This scenario involves 6 agents, divided into two groups of [2, 4]. These agents need to work collectively, using the imperfect information available to them, to track and capture two moving targets, ensuring effective communication to minimize collisions.
- **PP(2):** This setup includes 8 agents, categorized into two groups of [3, 5]. With the increase in the number of agents, they encounter greater challenges in collaboration and communication, especially when aiming to successfully capture two targets with limited information.

A.1.3 Traffic Junction (TJ)

The Traffic Junction scenarios emphasize the importance of navigation and collaboration in traffic conditions:

- **TJ(1)**: This setting encompasses 20 agents, each with a vision range of 1 unit. They are tasked with navigating an 18x18 grid map. Given their limited 80-step allowance and the map's high difficulty level, they must maneuver strategically to meet their objectives while preventing traffic jams and collisions.
- **TJ(2)**: This scenario unfolds on a slightly larger 21x21 grid map. With 30 agents, all equipped with a 1-unit vision range, the challenge is further amplified. The agents have a tight 80-step window to handle this challenging map, demanding precise teamwork to ensure smooth traffic flow.

A.2 Experimental results

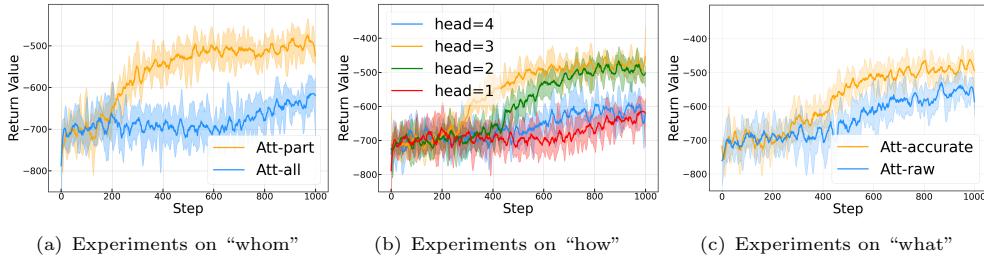


Fig. 10 Partial experimental results on CN1

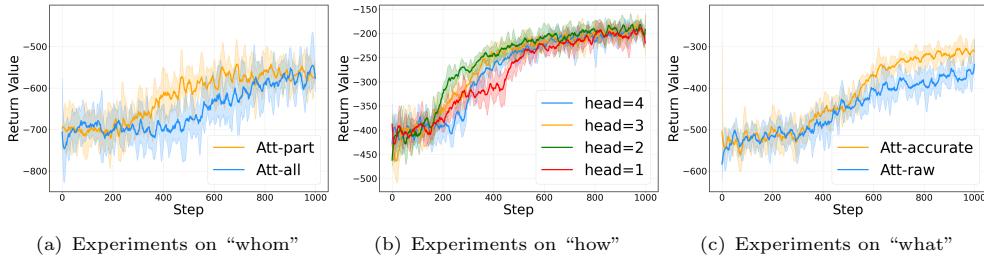
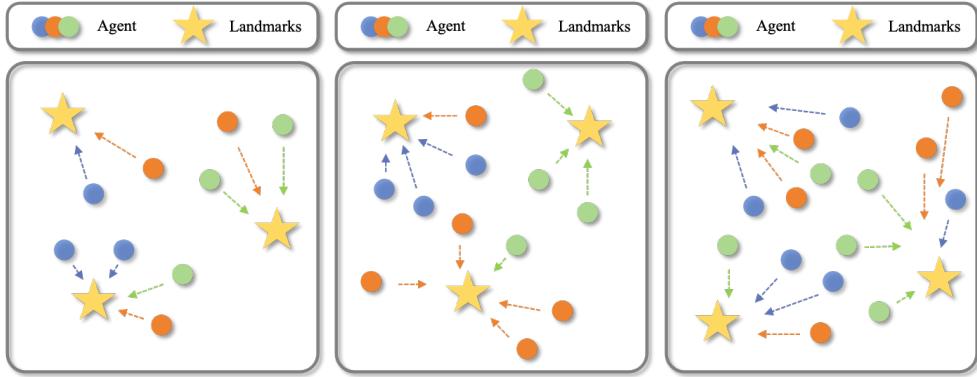
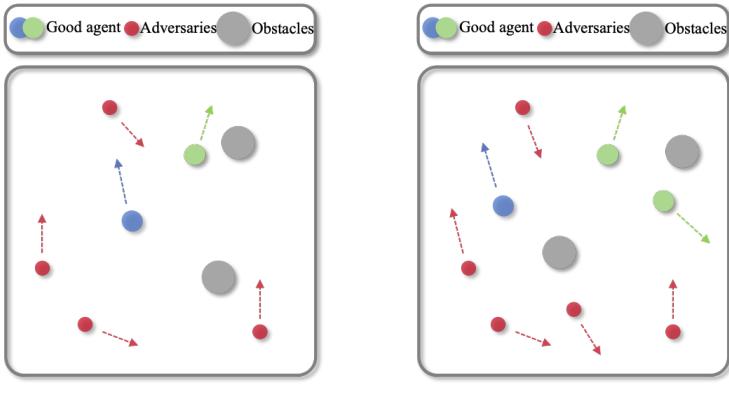


Fig. 11 Partial experimental results on CN2



(a) Cooperative Navigation CN(1) (b) Cooperative Navigation CN(2) (c) Cooperative Navigation CN(3)

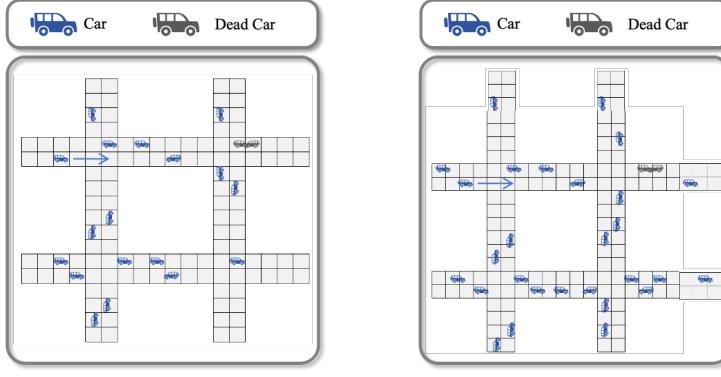
Fig. 12 In the Cooperative Navigation settings of the MPE environment, we've designed three distinct configurations, each with a unique agent distribution, to ensure every landmark is covered by at least one agent. These three images showcase these different setups.



(a) Predator and Prey PP(1)

(b) Predator and Prey PP(2)

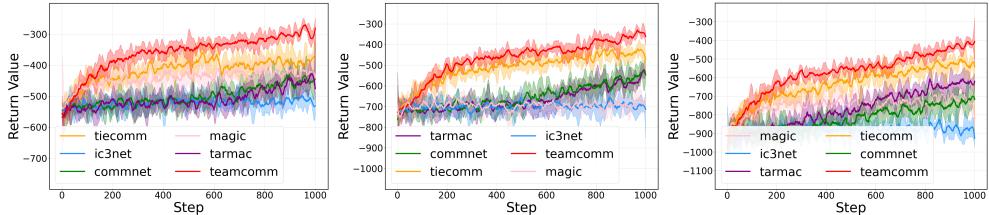
Fig. 13 In the Predator and Prey scenario inspired by the MPE environment, agents, unable to directly identify their type or others, must cooperate amidst inaccurate information to track targets, with two distinct setups showcased in the images, emphasizing the challenges of collaboration and communication.



(a) Traffic Junction TJ(1)

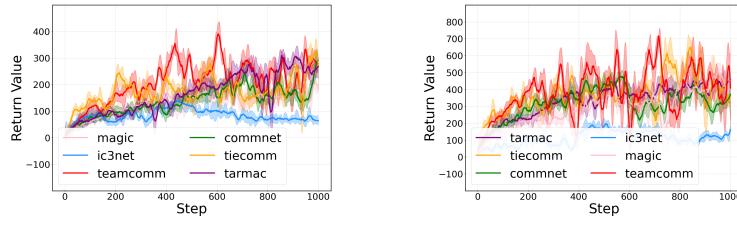
(b) Traffic Junction TJ(2)

Fig. 14 In the Traffic Junction scenarios, agents must navigate grid maps emphasizing strategic maneuvering to prevent traffic jams and collisions. These two images depict the challenges faced on grids of different sizes, along with their respective agent counts and vision limitations.



(a) Cooperative Navigation CN(1) (b) Cooperative Navigation CN(2) (c) Cooperative Navigation CN(3)

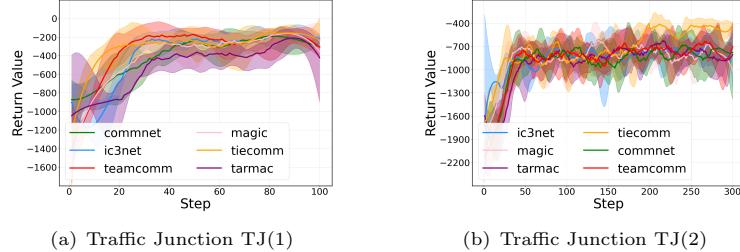
Fig. 15 In the cooperative navigation settings of MPE, three unique agent distribution configurations were designed to cover each landmark. Three images illustrate these configurations, and the data results show that, notably, the teamcomm represented by the red line significantly improved the collaboration ability of the agents, optimizing the effect of ensuring landmark coverage.



(a) Predator and Prey PP(1)

(b) Predator and Prey PP(2)

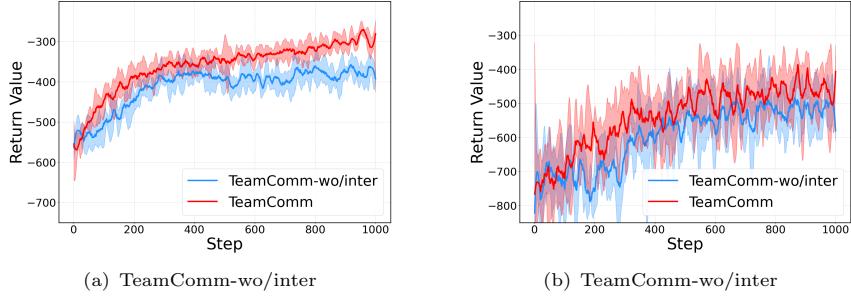
Fig. 16 In the Predator and Prey scenario modeled after the MPE environment, agents face the challenge of collaboration and communication amidst inaccurate information as they cannot directly identify their or others' types while tracking targets. Two different setups depicted in the images emphasize these challenges. In this environment, although our teamcomm method displays instability, it overall exhibits good performance, aiding in navigating the complexities and enhancing the collaborative efforts among agents.



(a) Traffic Junction TJ(1)

(b) Traffic Junction TJ(2)

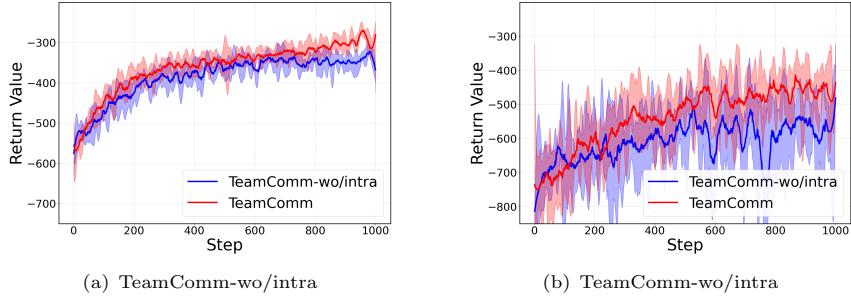
Fig. 17 In the Traffic Junction scenarios, agents are required to strategically maneuver on grid maps to prevent traffic jams and collisions. These two images depict the challenges encountered on grids of different sizes, along with their respective agent counts and vision limitations. In this environment, all methods quickly reached a performance bottleneck, showcasing the limits of each method, hence the difference in results is not very pronounced. However, in the two different setups, teamcomm did not show a significant advantage.



(a) TeamComm-wo/inter

(b) TeamComm-wo/inter

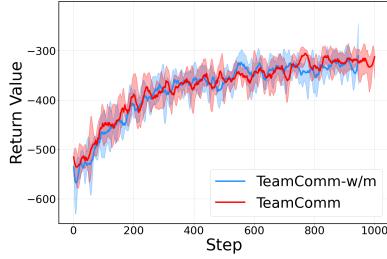
Fig. 18 Results with "inter" on RQ2 in different CN tasks



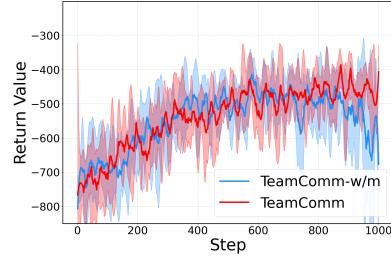
(a) TeamComm-wo/intra

(b) TeamComm-wo/intra

Fig. 19 Results with "intra" on RQ2 in different CN tasks

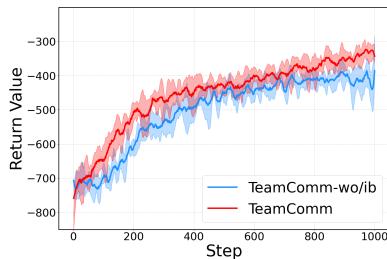


(a) TeamComm-w/m

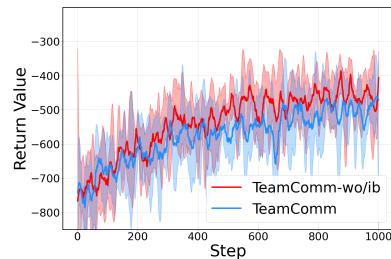


(b) TeamComm-w/m

Fig. 20 Results on RQ3 in different CN tasks



(a) TeamComm-wo/ib



(b) TeamComm-wo/ib

Fig. 21 Results on RQ4 in different CN tasks