Learning and Exploiting Shaped Reward Models for Large Scale Multiagent RL

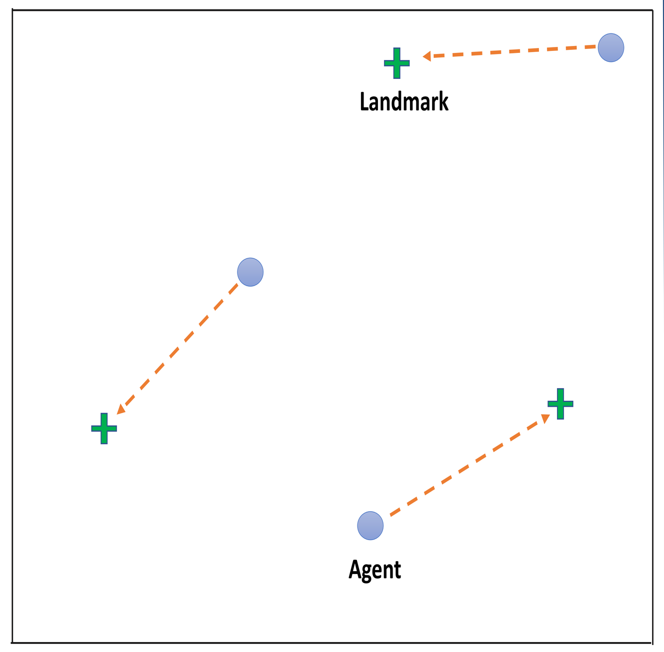
Arambam James Singh, Akshat Kumar and Hoong Chuin Lau, School of Computing & Information Systems, Singapore Management University
{arambamjs.2016, akshatkumar, hclau}@smu.edu.sg

Introduction

We address the problem of multiagent credit assignment in large scale multiagent system. Our main contributions are:

- An approach to learn a differentiable reward model by exploiting the collective nature of interactions among agents.
- A principled method to analytically compute shaped rewards from the reward model.
- A model-based RL approach that uses learned shaped rewards addressing credit assignment problem.

Motivating Domains



Air Traffic Control **Cooperative Navigation**

Challenges

- Empirical reward signal is not effective in addressing multiagent credit assignment problem.
- The credit assignment problem becomes more challenging with large number of agents.
- Current proposed approaches either do not scale well for large agent settings or their credit assignment mechanism is not effective.

Our work address these challenges.

Count Variables

State-Action Count Variable

$$\mathrm{n}_t(s,a) = \sum_{m=1}^{M} \mathbb{I}[s_t^m = s, a_t^m = a; \boldsymbol{s}_t, \boldsymbol{a}_t], \forall s \in S$$

System Reward Approximator

Loss Function for Reward Approximator

$$\tilde{\mathcal{L}}(\mathrm{w}) = M \sum_{\xi \in \mathcal{B}} \sum_{s \in S} \sum_{a \in A} \mathrm{n}_\xi(s,a) \cdot \left(\tilde{r}(s,a,\mathbf{n}_\xi^S) - r_{\mathrm{w}}(s,a,\mathbf{n}_\xi^S) \right)^2$$

Approximate DR – Discrete Action

Difference Rewards (DRs)

$$D^m\left(s_t^m, a_t^m\right) = r\left(\boldsymbol{s}_t, \boldsymbol{a}_t\right) - r\left(\boldsymbol{s}_t^{-m} \cup d_s, \boldsymbol{a}_t^{-m} \cup d_a\right)$$

Difference Rewards with Count Variables

$$D^m(s_t^m, a_t^m) = r_{\mathrm{w}}\left(\mathbf{n}_t^{SA}\right) - r_{\mathrm{w}}\left(\mathbf{n}_t^{SA-(s_t^m, a_t^m)+(d_s, d_a)}\right)$$

Approximate Difference Rewards

$$D_t(s,a) \approx \frac{1}{M} \cdot \left(\frac{\partial r_{\mathbf{w}}\left(\tilde{\mathbf{n}}_t^{SA}\right)}{\partial \tilde{\mathbf{n}}_t^{SA}(s,a)} - \frac{\partial r_{\mathbf{w}}\left(\tilde{\mathbf{n}}_t^{SA}\right)}{\partial \tilde{\mathbf{n}}_t^{SA}(d_s,d_a)} \right)$$

Return with Difference Rewards

$$R_t^{dr} = \sum_{i=0}^{\infty} \gamma^i \left(\sum_{s \in S} \sum_{a \in A} \mathrm{n}_{t+i}(s,a) \cdot D_{t+i}(s,a) \right)$$

Policy Gradient

$$\nabla_\theta J(\pi_\theta) = \mathbb{E}_{\boldsymbol{s}_{0:\infty}, \boldsymbol{a}_{0:\infty}} \left[\sum_{t=0}^{\infty} \sum_{s \in S} \sum_{a \in A} \mathrm{n}_t(s,a) \cdot \nabla_\theta \log \pi_\theta(a \mid s_t) \cdot R_t^{dr} \right]$$

Approximate DR - Continuous Actions

Continuous Action:

$$a^m = f_\theta(\epsilon^m; s^m)$$

Noise Partition

$$\underset{\epsilon^{k-1} \quad \epsilon^k}{k^{th}}$$

Difference Rewards

$$D^m\left(s_t^m, \epsilon_t^m\right) = r_\theta(\boldsymbol{s}_t, \boldsymbol{\epsilon}_t) - r_\theta(\boldsymbol{s}_t^{-m} \cup d_s, \boldsymbol{\epsilon}_t^{-m} \cup d_\epsilon)$$

Approximate Difference Rewards

$$D_t(i,k) \approx \frac{1}{M} \left(\frac{\partial r_{\mathrm{w}}\left(\mathrm{n}_t^S, \mathrm{n}_t^{SP}\right)}{\partial \mathrm{n}_t^S(i)} - \frac{\partial r_{\mathrm{w}}\left(\mathrm{n}_t^S, \mathrm{n}_t^{SP}\right)}{\partial \mathrm{n}_t^S(d_s)} + \frac{\partial r_{\mathrm{w}}\left(\mathrm{n}_t^S, \mathrm{n}_t^{SP}\right)}{\partial \mathrm{n}_t^{SP}(i,k)} - \frac{\partial r_{\mathrm{w}}\left(\mathrm{n}_t^S, \mathrm{n}_t^{SP}\right)}{\partial \mathrm{n}_t^{SP}(d_s, d_{k^*})} \right)$$

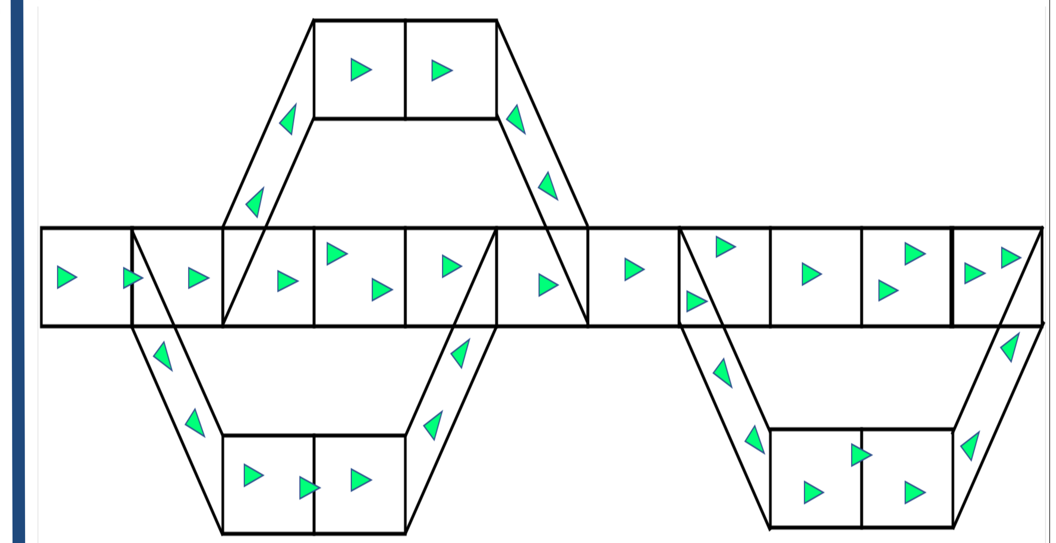
Soft Action-Critic with DR

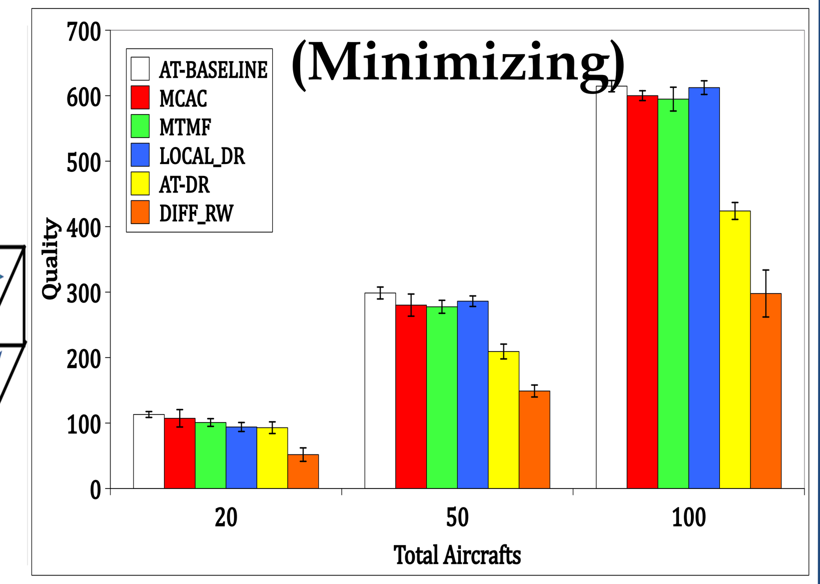
$$\hat{Q}(o^m(s_t), a_t^m) = D_t(o^m(s_t), k^m) + \gamma \mathbb{E}_{s_{t+1}} \left[V_{\bar{\psi}}(o^m(s_{t+1})) \right]$$

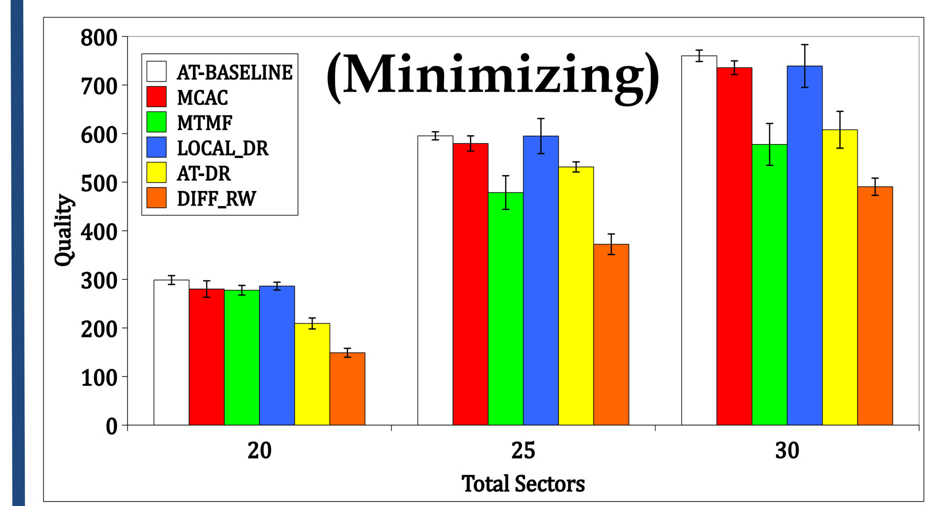
Experiments

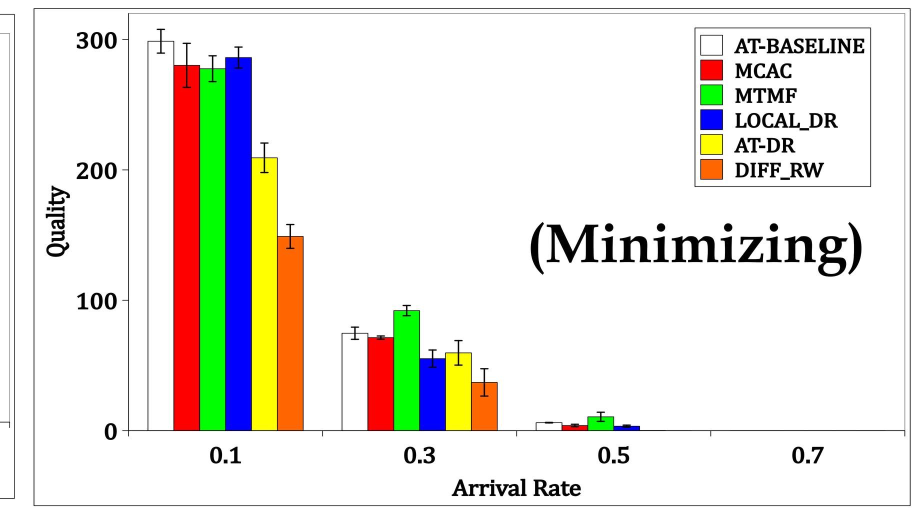
Air Traffic Control Problem

Synthetic Data:

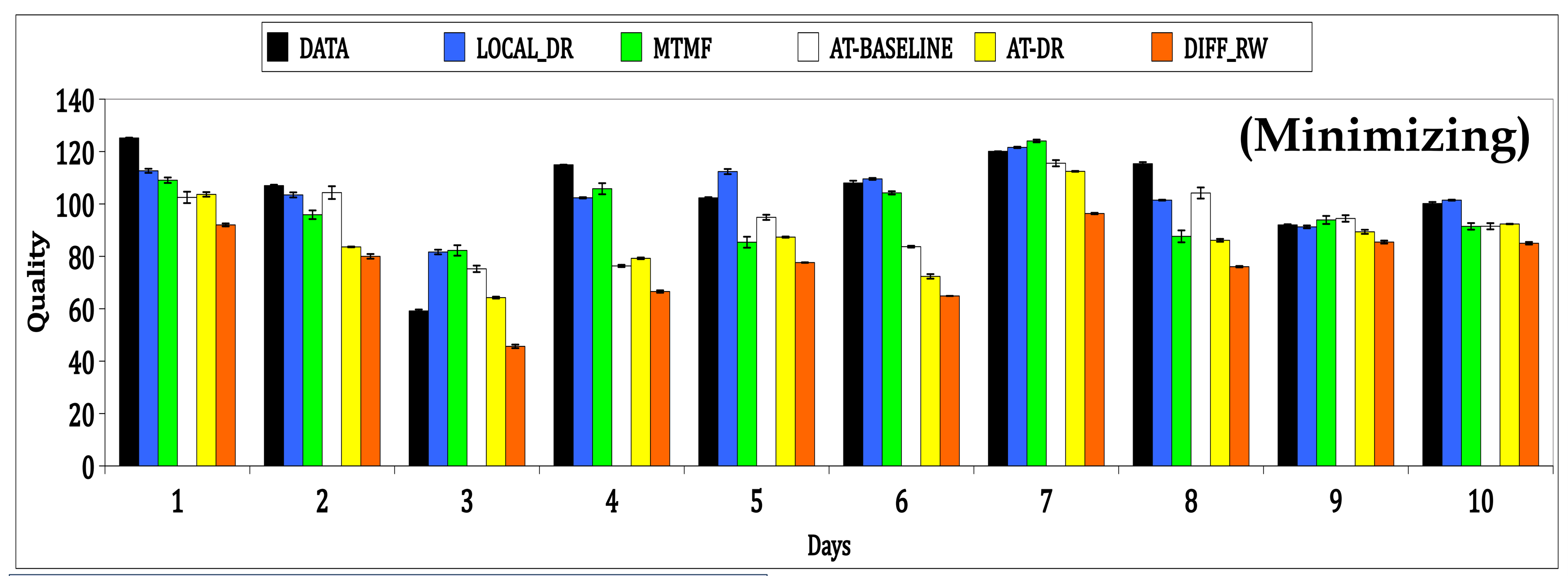




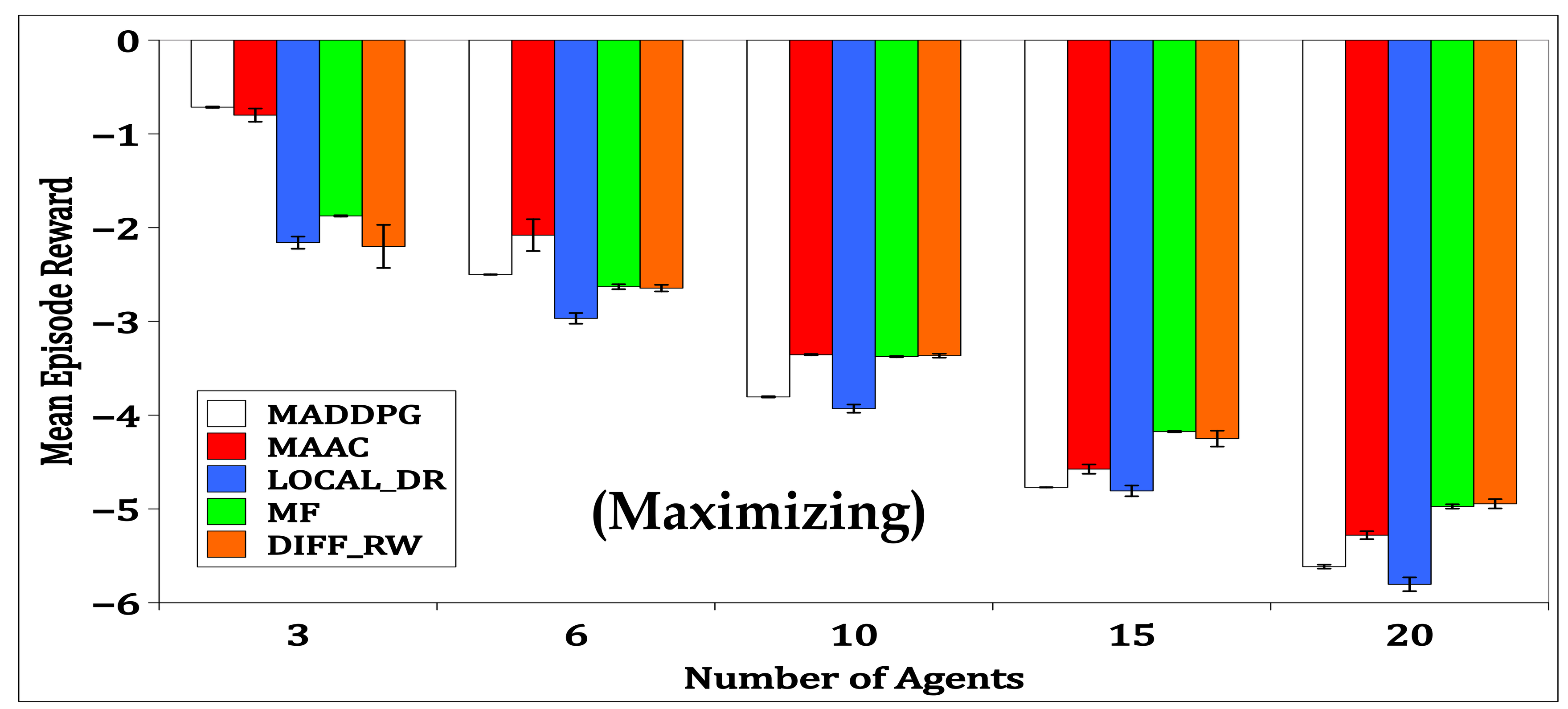




Real world dataset (1 month data):



Cooperative Navigation



Acknowledgments

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