

Physics-informed Value Learner for Offline Goal-Conditioned Reinforcement Learning

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Preliminaries

GCRL



Department of Computer Science

Preliminaries

Question

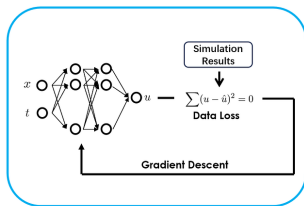
Can we introduce Physics-informed biases into the value learning step to improve **Value estimation** and **Value generalization**?

Physics-informed perspective on value learning

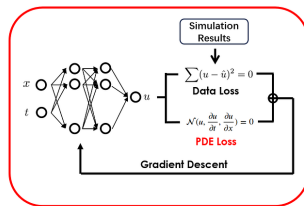
Hamilton-Jacobi-Bellman (HJB) Equation

Given $\dot{s}(t) = f(s(t), a(t))$, $t \geq 0$, the HJB for an undiscounted optimal control problem becomes

$$\inf_{a \in \mathcal{A}} [c(s, a) + \nabla_s V(s, g)^\top f(s, a)] = 0.$$



Traditional NN



Physics-informed NN

Eikonal PDE

HJB vs Eikonal

The following inequality holds

$$\inf_{a \in \mathcal{A}} [c(s, a) + \nabla_s V(s, g)^\top f(s, a)] \leq c^*(s) + \|\nabla_s V(s, g)\| F^*(s), \quad (1)$$

where $\dot{s}(t) = f(s(t), a(t))$, $c^*(s) = \inf_{a \in \mathcal{A}} c(s, a)$ and $F^*(s) = \sup_{a \in \mathcal{A}} \|f(s, a)\|$.

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Eik-HIQL

$$\begin{aligned} \mathcal{L}_V(\theta_V) = & \mathbb{E}_{(s, s') \sim \mathcal{D}, g \sim \mathcal{P}_g} \left[L_2^1(\mathcal{R}(s, g) + \gamma V_{\theta_V}(s', g) - V_{\theta_V}(s, g)) \right. \\ & \left. + (\|\nabla_s V_{\theta_V}(s, g)\| \cdot S(s) - 1)^2 \right] \end{aligned}$$

Goal-conditioned RL: Results

Eik HIQL vs HIQL

Goal-conditioned RL: Results

Environment	Dataset	Dim	Ek-HIQL	HIQL	QRL	CRL
pointmaze	navigate	medium	93 $\pm$ 5	92 $\pm$ 2	83 $\pm$ 3	54 $\pm$ 19
		large	83 $\pm$ 9	49 $\pm$ 13	90 $\pm$ 5	56 $\pm$ 9
		giant	79 $\pm$ 13	7 $\pm$ 8	72 $\pm$ 7	37 $\pm$ 17
		teleport	47 $\pm$ 10	29 $\pm$ 7	34 $\pm$ 7	50 $\pm$ 5
	stitch	medium	96 $\pm$ 3	76 $\pm$ 8	80 $\pm$ 10	3 $\pm$ 5
		large	73 $\pm$ 6	19 $\pm$ 7	85 $\pm$ 11	4 $\pm$ 6
		giant	22 $\pm$ 10	1 $\pm$ 4	56 $\pm$ 9	0 $\pm$ 0
		teleport	43 $\pm$ 9	38 $\pm$ 5	42 $\pm$ 6	12 $\pm$ 6
antmaze	navigate	medium	95 $\pm$ 1	96 $\pm$ 1	87 $\pm$ 5	94 $\pm$ 2
		large	86 $\pm$ 2	90 $\pm$ 6	80 $\pm$ 5	86 $\pm$ 3
		giant	67 $\pm$ 5	69 $\pm$ 3	14 $\pm$ 6	18 $\pm$ 4
		teleport	52 $\pm$ 4	43 $\pm$ 3	39 $\pm$ 4	55 $\pm$ 4
	stitch	medium	94 $\pm$ 2	95 $\pm$ 14	68 $\pm$ 6	54 $\pm$ 8
		large	84 $\pm$ 3	74 $\pm$ 6	24 $\pm$ 5	13 $\pm$ 4
		giant	48 $\pm$ 11	3 $\pm$ 3	2 $\pm$ 2	0 $\pm$ 0
		teleport	47 $\pm$ 2	35 $\pm$ 3	29 $\pm$ 6	34 $\pm$ 4
	explore	medium	43 $\pm$ 15	33 $\pm$ 15	5 $\pm$ 4	4 $\pm$ 2
		large	13 $\pm$ 1	6 $\pm$ 7	0 $\pm$ 0	0 $\pm$ 0
		teleport	15 $\pm$ 10	45 $\pm$ 5	2 $\pm$ 2	22 $\pm$ 5
humanoidmaze	navigate	medium	86 $\pm$ 2	90 $\pm$ 3	22 $\pm$ 2	61 $\pm$ 4
		large	64 $\pm$ 7	50 $\pm$ 4	7 $\pm$ 3	22 $\pm$ 9
		giant	68 $\pm$ 5	18 $\pm$ 5	1 $\pm$ 1	4 $\pm$ 2
	stitch	medium	79 $\pm$ 2	88 $\pm$ 3	22 $\pm$ 4	40 $\pm$ 7
		large	29 $\pm$ 7	28 $\pm$ 2	3 $\pm$ 1	4 $\pm$ 2
		giant	19 $\pm$ 5	3 $\pm$ 1	0 $\pm$ 0	0 $\pm$ 0
antsoccer	navigate	arena	19 $\pm$ 2	60 $\pm$ 4	10 $\pm$ 3	24 $\pm$ 2
		medium	3 $\pm$ 2	13 $\pm$ 3	2 $\pm$ 2	4 $\pm$ 2
	stitch	arena	2 $\pm$ 0	17 $\pm$ 3	2 $\pm$ 1	1 $\pm$ 1
		medium	1 $\pm$ 0	5 $\pm$ 1	0 $\pm$ 0	0 $\pm$ 0
manipulation	cube-single-play		25 $\pm$ 1	31 $\pm$ 4	11 $\pm$ 3	32 $\pm$ 2
	scene-play		52 $\pm$ 7	52 $\pm$ 3	8 $\pm$ 2	35 $\pm$ 6

Thank you!