ISCAS 中国科学院软件研究所学术年会'2022
暨计算机科学国家重点实验室开放周
学术论文

A Closed-Loop Perception, Decision-Making and Reasoning Mechanism for Human-Like Navigation

基于感知、决策和推理闭环机制的仿人导航

Wenqi Zhang, Kai Zhao, Peng Li, Xiao Zhu, Yongliang Shen, Yanna Ma, Yingfeng Chen and Weiming Lu
作者单位：浙江大学、网易伏羲机器人、中科院软件所
联系人：李鹏，18611822168，lipeng@iscas.ac.cn、
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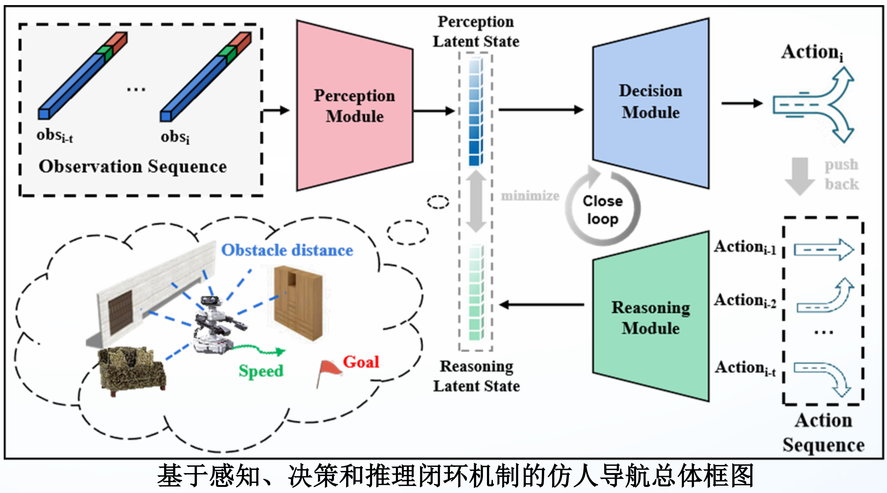


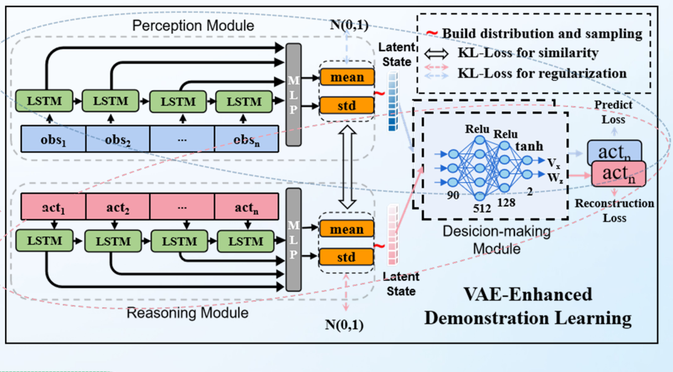
基于感知、决策和推理闭环机制的仿人导航总体框图

Prediction-Denoise-channel.

$$\mu_t^P, \sigma_t^P = \mathrm{MLP}^P(\mathrm{LSTM}^P(o_{t-n:t}))$$
$$s_t^P \sim N(\mu_t^P, \sigma_t^P)$$
$$a_t^{pred} = \mathrm{MLP}^D(s_t^P)$$

Reconstruction-VAE-channel.

$$KL(R(s|A)\|p^*(s|a)) = \int R(s|A)\log\frac{R(s|A)}{p^*(s|a)}ds$$
$$= \int R(s|A)\log\frac{R(s|A)}{p^*(s)}ds - \int R(s|A)\log p(a|s)ds$$
$$= KL(R(s|A)\|p^*(s)) - E_{s\sim R(s|A)}[\log p(a|s)]$$
$$= KL(R(\cdot)\|p^*(s)) - E_{s\sim R(\cdot)}[\log D(\cdot)]$$



$$\mu_t^R, \sigma_t^R = \mathrm{MLP}^R(\mathrm{LSTM}^R([a_t^{pred}; a_{t-n:t-1}^{real}]))$$
$$R_t^{sim} = \mathrm{Prob}(\mu_t^P \mid N(\mu_t^R, \sigma_t^R))$$

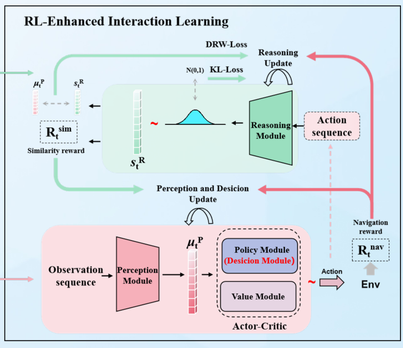
Optimization for reasoning:

$$L_{1,t}^R = R_t^{discount} * \|\mu_t^P - s_t^R\|_2^2$$
$$L_{2,t}^R = (-1 - \log\sigma_t^R + (\mu_t^R)^2 + \sigma_t^R)$$

$$\mu_t^P = \mathrm{MLP}^P(\mathrm{LSTM}^P([o_t; o_{t-n:t-1}]))$$
$$a_t^{pred} = \mathrm{MLP}^D(\mu_t^P)$$

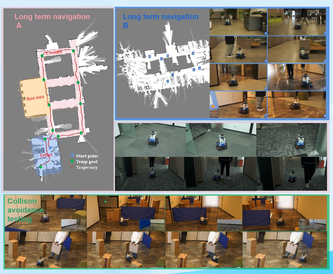
Optimization for perception and decision-making:

$$R_t = R_t^{sim}/\rho + R_t^{nav}$$



Zero-shot scene benchmark	Metrics mean/std	S_1+Density change	S_2+Shape change	S_3+Density change	S_4+Speed change	S_5+Volume change	S_6+Obstacle change	S_7+Edge change	S_8+View change	AVG
One-stage method										
Move-base	SR	60%	70%	65%	10%	75%	15%	65%	30%	48.75%
DM-RCA	SR	47.50%(3.7)	69.75%(4.5)	59.25%(3.3)	48.25%(3)	78%(4.6)	62.75%(6.9)	87.75%(4.7)	73.5%(5)	65.84%
	AS	229(20)	245(20)	218(44)	299(20)	226(17)	**167**(24)	210(16)	191(15)	223
PPO	SR	27%(3.4)	52%(7.8)	41%(5.8)	26.25%(6.4)	52%(8)	44.5%(4.6)	86.75%(2.1)	76%(5)	50.69%
	AS	262(22)	304(107)	521(124)	241(39)	372(98)	281(87)	240(4)	293(27)	314
Two-stage method										
MOE-VUCA	SR	25%(2)	64%(8)	40%(3.9)	39.5%(4)	58%(9.2)	63.25%(3.3)	86%(3.6)	34%(6.1)	51.22%
	AS	**176**(28)	**194**(23)	**134**(37)	**143**(24)	**161**(46)	184(64)	**186**(73)	**98**(20)	**159**
DM-RCA*	SR	75%(1)	81.5%(3.2)	48%(2.8)	52%(7.8)	85%(1.7)	82.5%(1.3)	93.5%(0.8)	65%(7.7)	72.81%
	AS	250(15)	214(26)	276(96)	263(12)	237(9)	233(66)	204(19)	230(27)	238
PPO*	SR	29.25%(3.9)	64%(4)	35.25%(5.4)	42.75%(6.3)	50.75%(5)	49%(0.9)	93.75%(2.1)	**79.75**%(4.5)	55.56%
	AS	653(100)	376(80)	299(50)	444(67)	485(88)	198(22)	227(4)	226(15)	363
Ours	SR	**84.5**%(1.2)	**83.75**%(1.7)	**69.5**%(1.1)	**56**%(1.9)	**88**%(4.0)	**83**%(3.2)	**95.5**%(0.8)	74.5%(4.3)	**79.34**%
	AS	426(33)	386(37)	344(22)	383(56)	391(50)	239(44)	250(24)	313(18)	341

仿真结果



实体机器人实验结果