

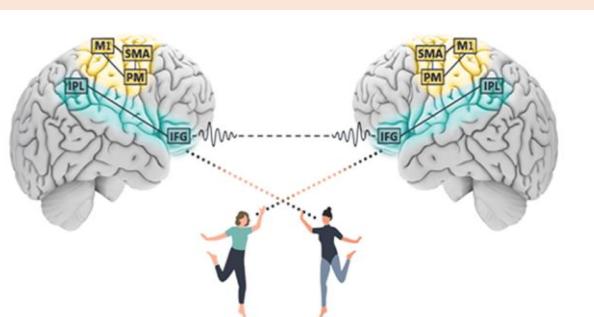
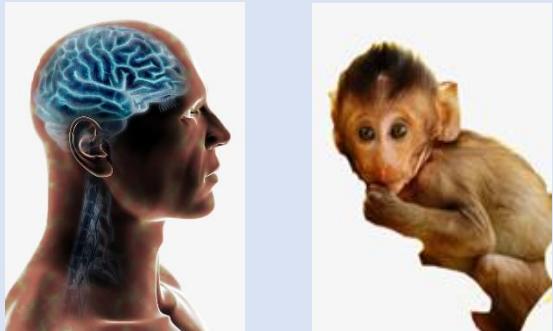
具身智能-01

刘华平

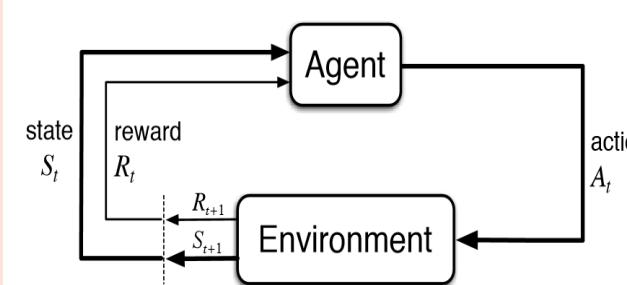
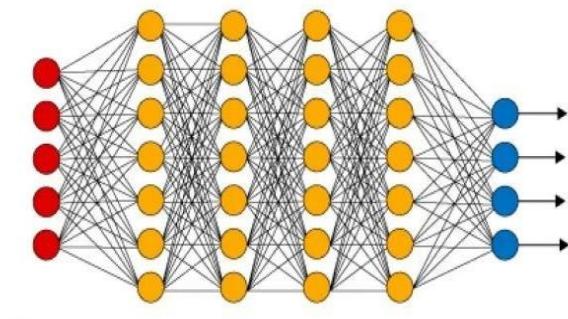
2024年2月19日

计算智能与机器入学→具身智能

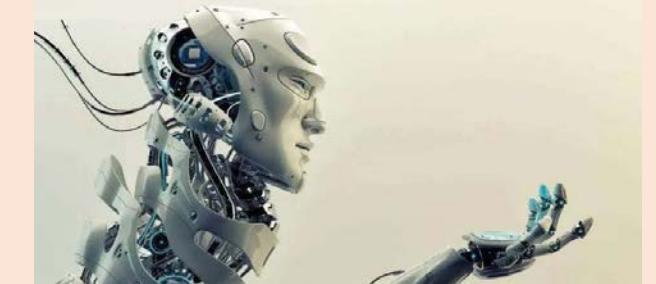
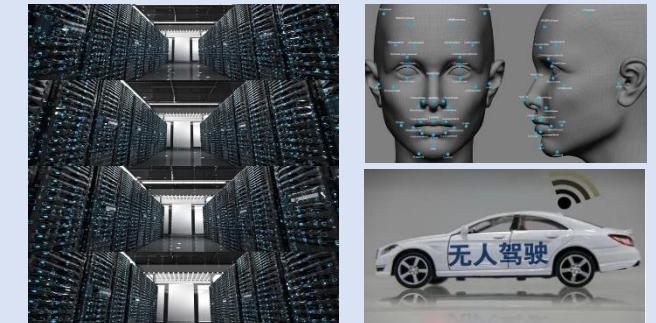
智能



计算



机器人



➤ 课程更名前后的内在关联



Angelo Cangelosi
曼彻斯特大学教授
Turing Fellow

具身智能领域的发展和
计算智能与机器学习紧
密关联

Embodyed in 37. Embodied Intelligence

Angelo Cangelosi, Josh Bongard, Martin H. Fischer, Stefano Nolfi

Embodied intelligence is the computational approach to the design and understanding of intelligent behavior in embodied and situated agents through the consideration of the strict coupling between the agent and its environment (situatedness), mediated by the constraints of the agent's own body, perceptual and motor system, and brain (embodiment). The emergence of the field of embodied intelligence is closely linked to parallel developments in computational intelligence and robotics, where the focus is on morphological computation and sensory-motor coordination in evolutionary robotics models, and in neuroscience and cognitive sciences where

37.1	Introduction to Embodied Intelligence .	697
37.2	Morphological Computation for Body-Behavior Coadaptation	698
37.2.1	The Counterintuitive Nature of Morphological Computation ...	699
37.2.2	Evolution and Morphological Computation	700
37.3	Sensory-Motor Coordination in Evolving Robots	701
37.3.1	Enabling the Discovery of Simple Solutions	701
37.3.2	Accessing and Generating Information Through Action	702
37.3.3	Channeling the Course of the Learning Process	703

-
- 1 具身智能的背景
 - 2 具身智能的体系
 - 3 具身智能的关键技术
 - 4 具身智能的前沿发展

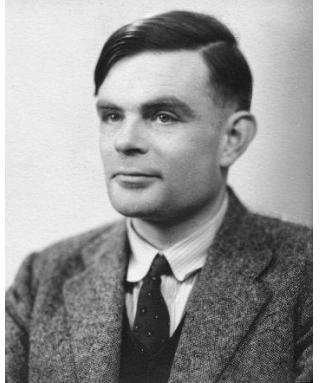


HISTORIANS ESTIMATE THAT BREAKING ENIGMA
SHORTENED THE WAR BY MORE THAN TWO YEARS,
SAVING OVER 14 MILLION LIVES.

历史学家认为英格玛密码的破解
使二战缩短了至少两年 拯救了超过一千四百万人的生命

1 背景

➤ 人工智能的发展



COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. The Imitation Game

I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think." The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words "machine" and "think" are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, "Can machines think?" is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

In the process of trying to imitate an adult human mind we are bound to think a good deal about the process which has brought it to the state that it is in. We may notice three components,

- (a) The initial state of the mind, say at birth,
- (b) The education to which it has been subjected,
- (c) Other experience, not to be described as education, to which it has been subjected.

Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child-brain is something like a notebook as one buys it from the stationers. Rather little mechanism, and lots of blank sheets. (Mechanism and writing are from our point of view almost synonymous.) Our hope is that there is so little mechanism in the child-brain that something like it can be easily programmed. The amount of work in the education we can assume, as a first approximation, to be much the same as for the human child.

We may hope that machines will eventually compete with men in all purely intellectual fields. But which are the best ones to start with? Even this is a difficult decision. Many people think that a very abstract activity, like the playing of chess would be best. It can also be maintained that it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. This process could follow the normal teaching of a child. Things would be pointed out and named, etc. Again I do not know what the right answer is, but I think both approaches should be tried.

We can only see a short distance ahead, but we can see plenty there that needs to be done.

我们的目光所及，只是
不远的前方。

早在1950年，图灵就曾在他的经典论文《计算机械与智能》中提到，人工智能的未来将走向两条路：一条是“计算的智能体”，即像阿尔法狗一样依赖强大计算力的大模型；另一条路则是“**具身智能**”，机器拥有像婴儿一样的感知能力，通过与环境的互动和学习不断进化。换句话说，具身智能并不是最近才火的概念，它的源流可以追溯到人工智能的最早理论。

1 背景

➤ 什么是具身智能

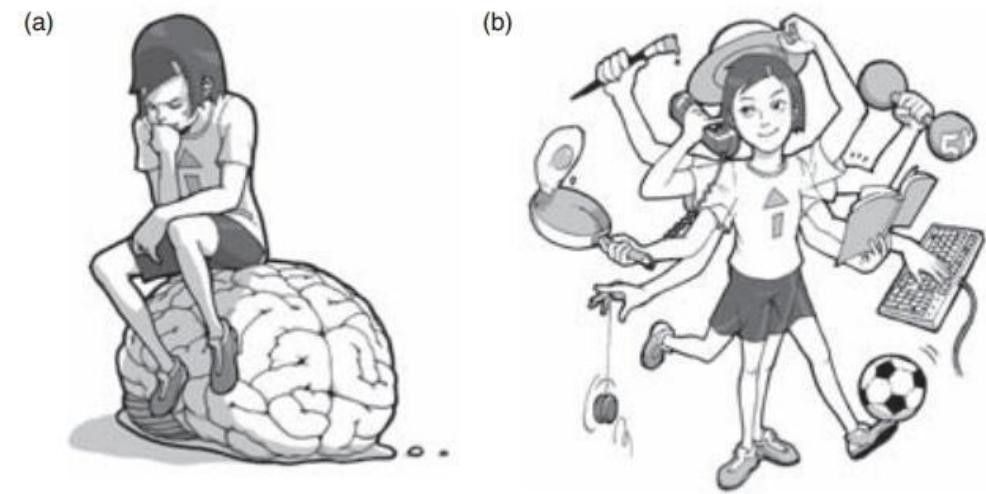
The embodiment hypothesis is the idea that intelligence emerges in the **interaction** of an agent with an environment and as a result of **sensorimotor** activity.

——Smith and Gasser

- ✓ Be Multimodal
- ✓ Be Incremental
- ✓ Be Physical
- ✓ Explore
- ✓ Be Social
- ✓ Learn a Language



身体利用感知-运动系统在
与环境交互过程中产生智能



- L. Smith and M. Gasser, "The development of embodied cognition: six lessons from babies.,," Artificial life, vol. 11, no. 1-2, 2005.

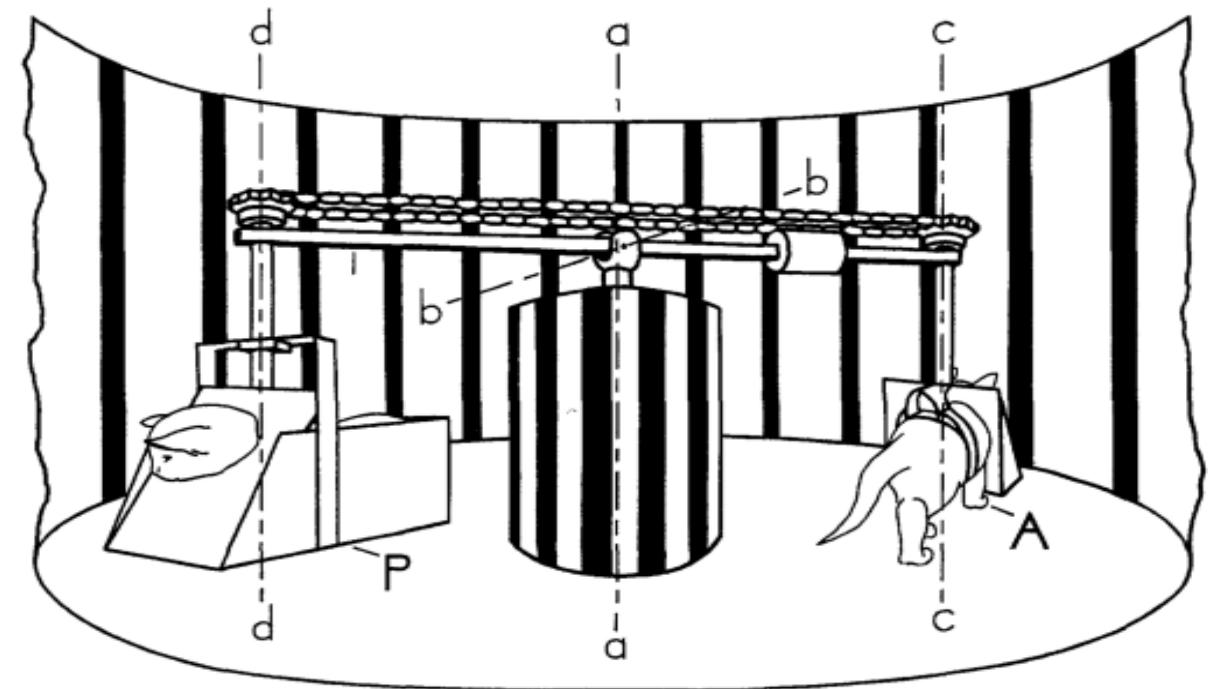
1 背景

➤ 无处不在的具身智能



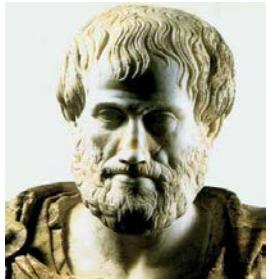
1 背景

➤ 极端的例子



1 背景

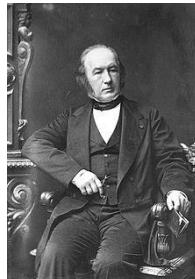
➤ 很长的过去



Aristotle
(公元前384-前322)



Charles Robert Darwin
(1809-1882)



Claude Bernard
(1813-1878)



Walter Bradford Cannon
(1871-1945)



Jean Piaget
(1896-1980)



James J. Gibson
(1904-1979)

身体的主动性首先在于
“通过触摸而感觉”

心境和动作之间的联系
就是情感的真正含义

“没有脑袋”的生理学

身体的智慧

动作是认识的源泉

感知与动作在与环境
交互中密切联系



René Descartes
1596-1650

我思故我在



Martin Heidegger
(1889-1976)

《存在与时间》
比表征更基本的活动
是操劳



Maurice Merleau-Ponty
(1908-1961)

知觉现象学：身体和主
体其实是同一个实在



Norbert Wiener
(1894-1964)

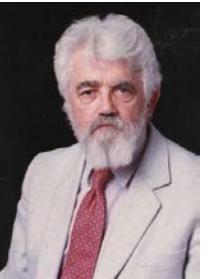
控制论

1 背景

➤ 很短的历史



Marvin Lee Minsky
(1927-2016)



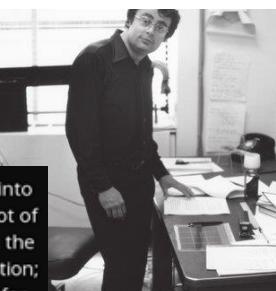
达特茅斯会议
(1956)



John Haugeland
(1945-2010)

GOF AI

- 人类认知和思维的基本单元是符号，而认知过程就是在符号表示上的一种运算。
- 人和计算机都是物理符号系统,因此可以用计算机来模拟人的智能行为,即用计算机的符号操作来模拟人的认知过程。
- 启发式算法 → **专家系统** → 知识工程



David Marr
(1945-1980)

When David Marr at MIT moved into computer vision, he generated a lot of excitement, but he hit up against the problem of knowledge representation; he had no good representations for knowledge in his vision systems.
— Marvin Minsky —

心有余而力不足

The spirit is willing, but the flesh is weak



The vodka is good but the meat is spoiled

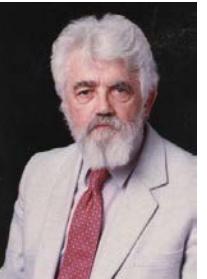
1 背景

➤ 很短的历史



Marvin Lee Minsky John McCarthy
(1927-2016) (1927-2011)

达特茅斯会议 (1956)

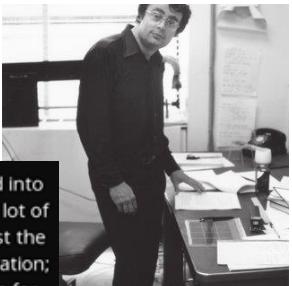


McCarthy
(2011)



John Haugeland (1945-2010)

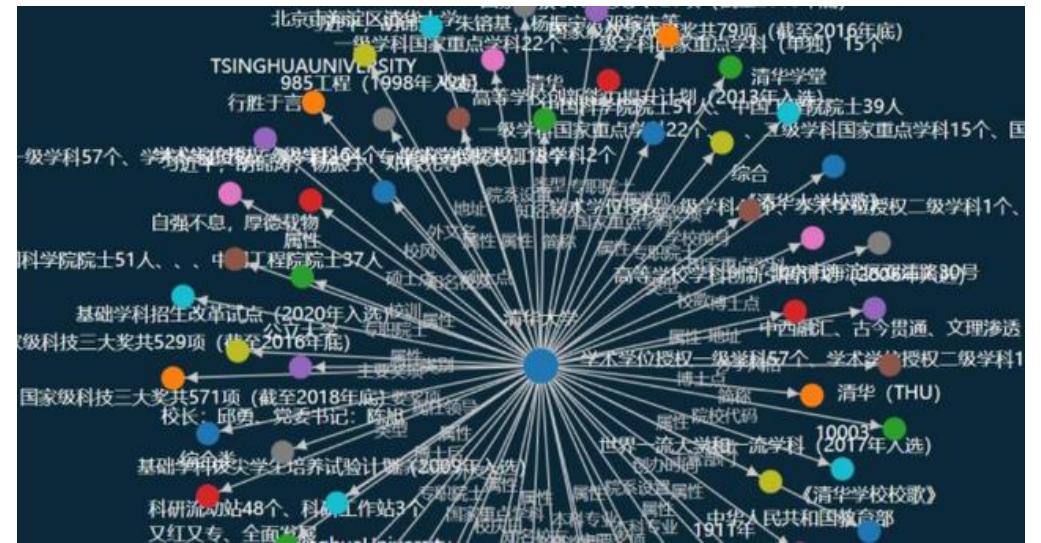
GOF AI



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— Marvin Minsky —

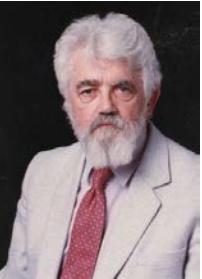
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 - 人和计算机都是物理符号系统,因此可以用计算机来模拟人的智能行为,即用计算机的符号操作来模拟人的认知过程。
 - 启发式算法 → 专家系统 → 知识工程



➤ 很短的历史



Marvin Lee Minsky
(1927-2016)
John McCarthy
(1927-2011)
达特茅斯会议
(1956)



John Haugeland
(1945-2010)
GOF AI



Hopfield
(1933-)



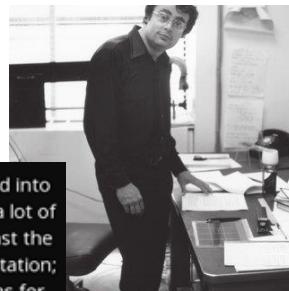
Rumelhart
(1942-2011)



Hilton
(1947-)

- 数据挖掘
- 机器学习
- 模式识别

神经网络->反向传播->深度学习



When David Marr at MIT moved into computer vision, he generated a lot of excitement, but he hit up against the problem of knowledge representation; he had no good representations for knowledge in his vision systems.
— Marvin Minsky —

David Marr
(1945-1980)

- 1950年Marvin Minsky和Dean Edmonds建造了第一台神经网络计算机SNARC，使用3000个真空管和自动指示装置模拟40个神经元构成的网络。

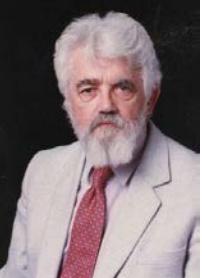


如果它现在不是，
那么总有一天会是

➤ 很短的历史



Marvin Lee Minsky
(1927-2016)
John McCarthy
(1927-2011)
达特茅斯会议
(1956)



John Haugeland
(1945-2010)
GOF AI



Hopfield
(1933-)

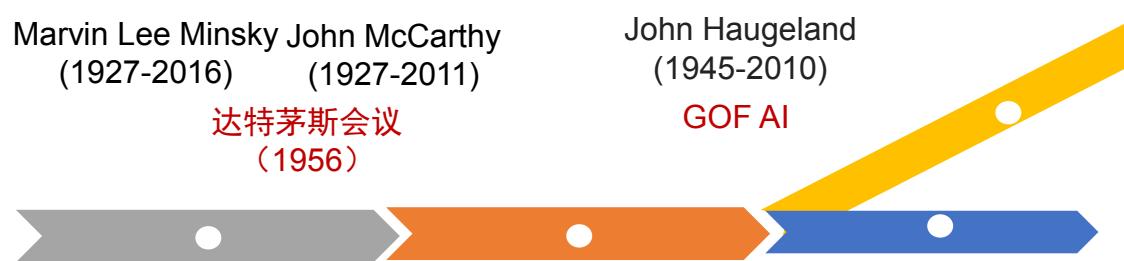


Rumelhart
(1942-2011)

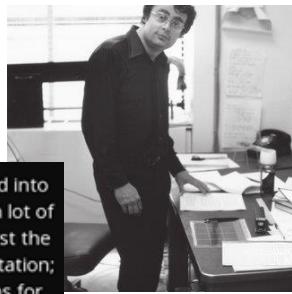


Hilton
(1947-)

- 数据挖掘
- 机器学习
- 模式识别



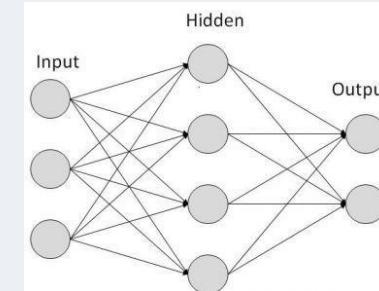
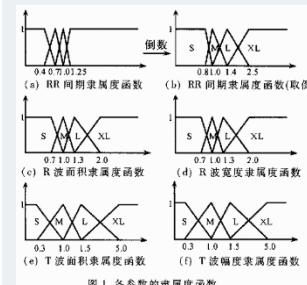
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David Marr
(1945-1980)

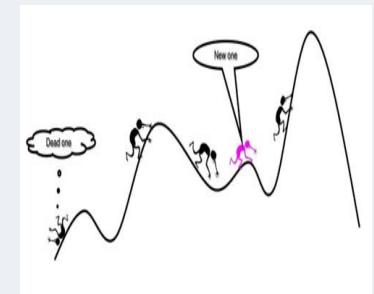
神经网络->反向传播->深度学习

计算智能



模糊逻辑表示

神经网络学习

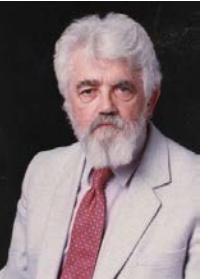


遗传算法优化

➤ 很短的历史



Marvin Lee Minsky
(1927-2016)
John McCarthy
(1927-2011)
达特茅斯会议
(1956)



John Haugeland
(1945-2010)
GOF AI



Hopfield
(1933-)

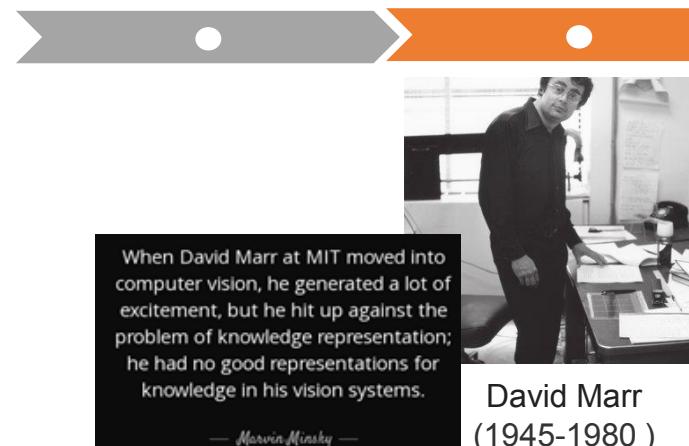


Rumelhart
(1942-2011)



Hilton
(1947-)

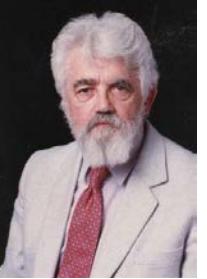
- 数据挖掘
- 机器学习
- 模式识别



➤ 很短的历史



Marvin Lee Minsky
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(1956)



John Haugeland
(1945-2010)
GOF AI



Hopfield
(1933-)



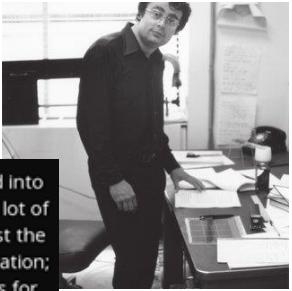
Rumelhart
(1942-2011)



Hilton
(1947-)

- 数据挖掘
- 机器学习
- 模式识别

神经网络->反向传播->深度学习



David Marr
(1945-1980)

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— Marvin Minsky —

已经在“人类最后智力骄傲”上碾压人类的AlphaGo ...



却连挪动一枚小小的棋子都需要人类帮助才能完成

➤ 人工智能的发展

**The Past and Future of
Robotics and Machine Intelligence
Based on 250 Years of Research
Experience**

Tues Sept 5 12-1pm
Banatao Auditorium

Ruzena Bajcsy and colleagues:

Rod Brooks, Ken Goldberg, Jitendra Malik
Shankar Sastry, and Claire Tomlin

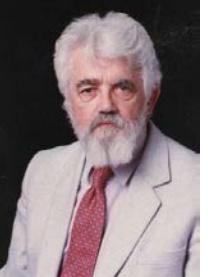


1 背景

➤ 很短的历史



Marvin Lee Minsky
(1927-2016)



达特茅斯会议
(1956)



John Haugeland
(1945-2010)

GOF AI



Hopfield
(1933-)



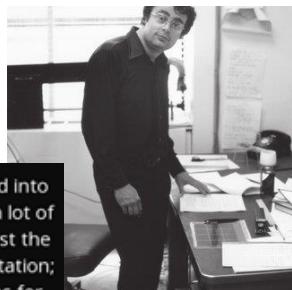
Rumelhart
(1942-2011)



Hilton
(1947-)

- 模式识别
- 数据挖掘
- 机器学习

神经网络->反向传播->深度学习



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— Marvin Minsky —

David Marr
(1945-1980)



Pfeifer
(1947-)



Moravec
(1948-)



Brooks
(1954-)



Cangelosi
(1967-)

- 机器人学
- 机构学
- 形态智能

• 智能是具身化和情境化的，智能需要一个身体

• 强化

➤ 莫拉维克悖论

要让电脑如成人般地下棋是相对容易的，但是要让电脑有如一岁小孩般的感知和行动能力却是相当困难的。



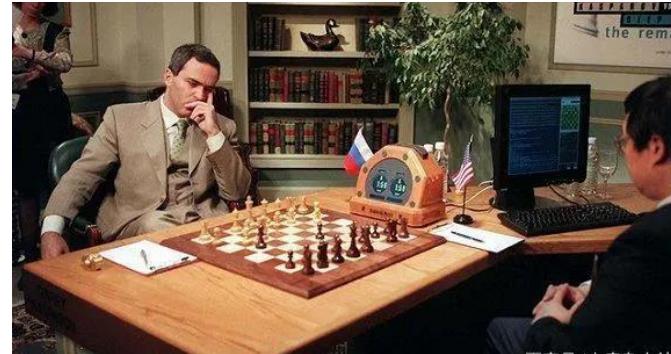
Hans Moravec



Donald Knuth

人工智能已经在几乎所有需要思考的领域超过了人类，但是在那些人类和其它动物不需要思考就能完成的事情上，还差得很远。

——Donald Knuth (2019)



1997: IBM的DeepBlue战胜卡斯帕罗夫



2016: DeepMind的AlphaGo” 战胜李世石

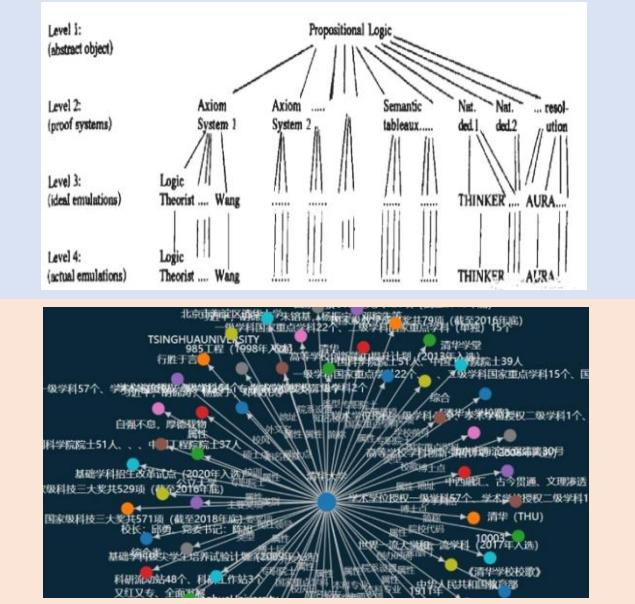


1 背景

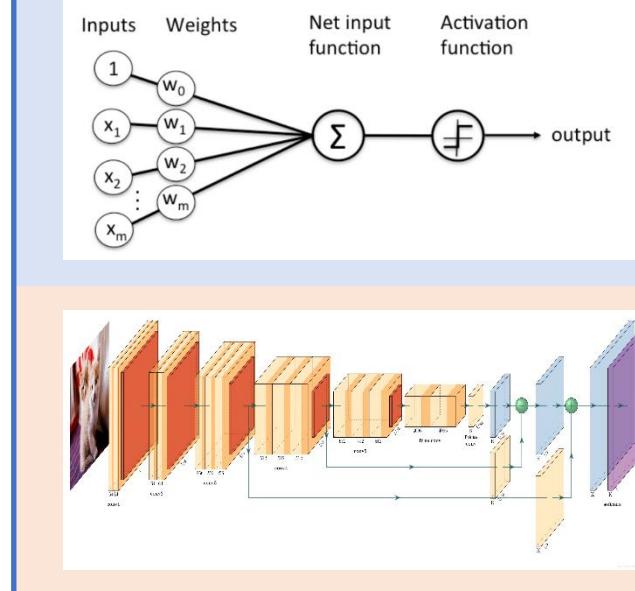
➤ 离身智能 v. s. 具身智能

具身智能

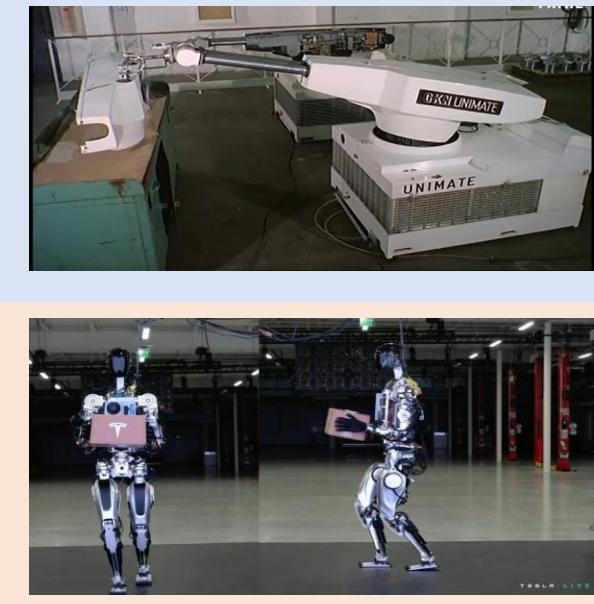
符号主义：表示



联结主义：计算



行为主义：交互



离身智能

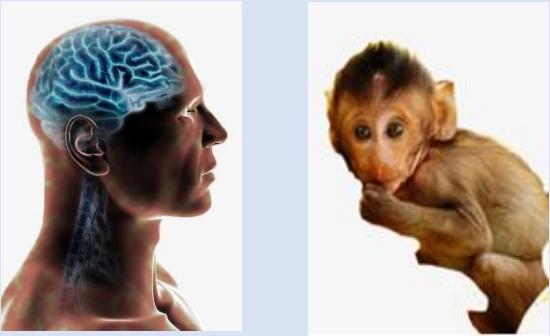
1 背景

➤ 共同的目标

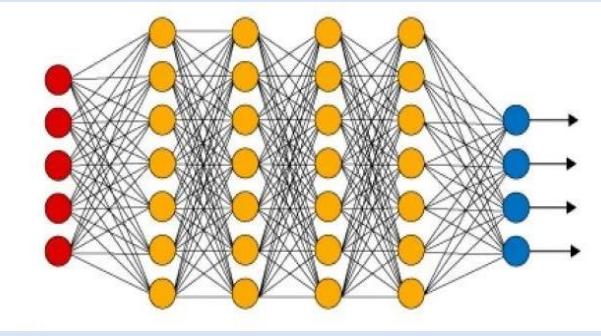
离身智能

具身智能

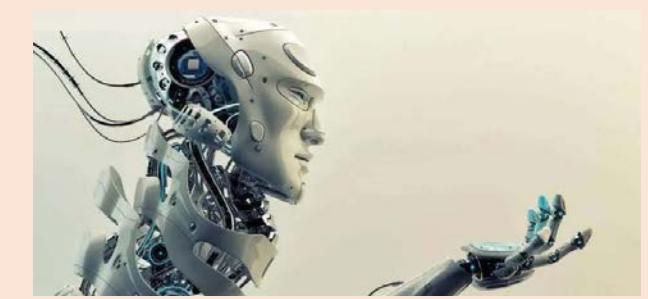
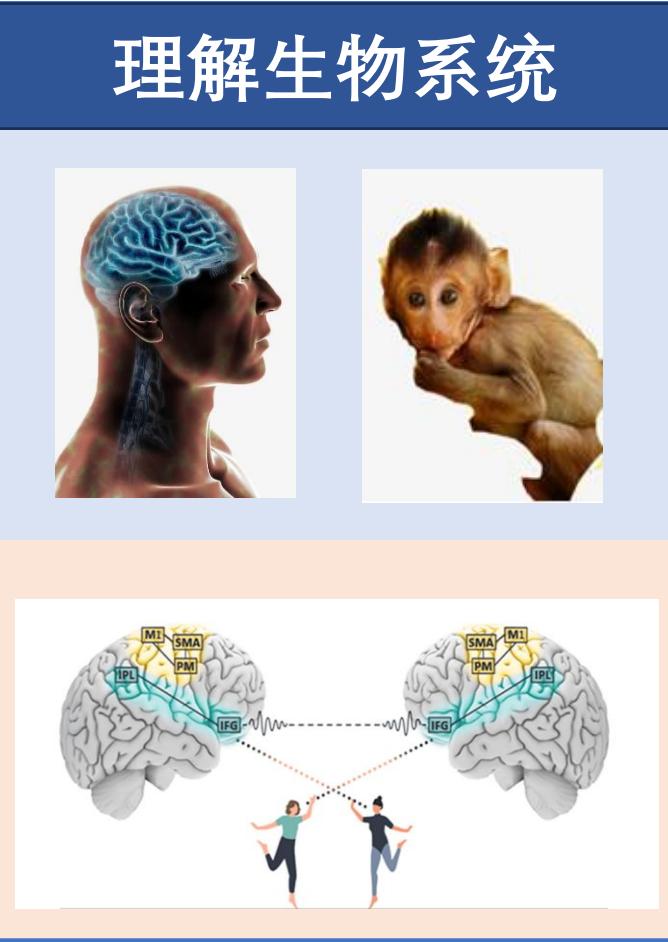
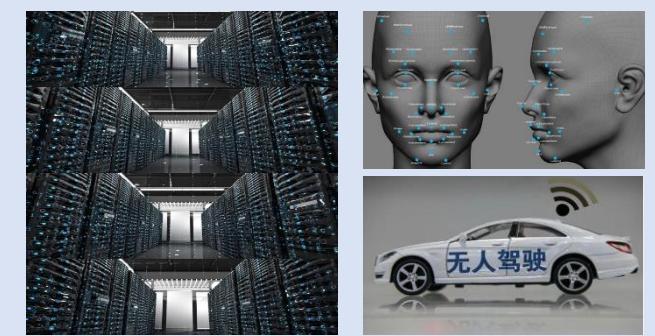
理解生物系统



智能行为的抽象

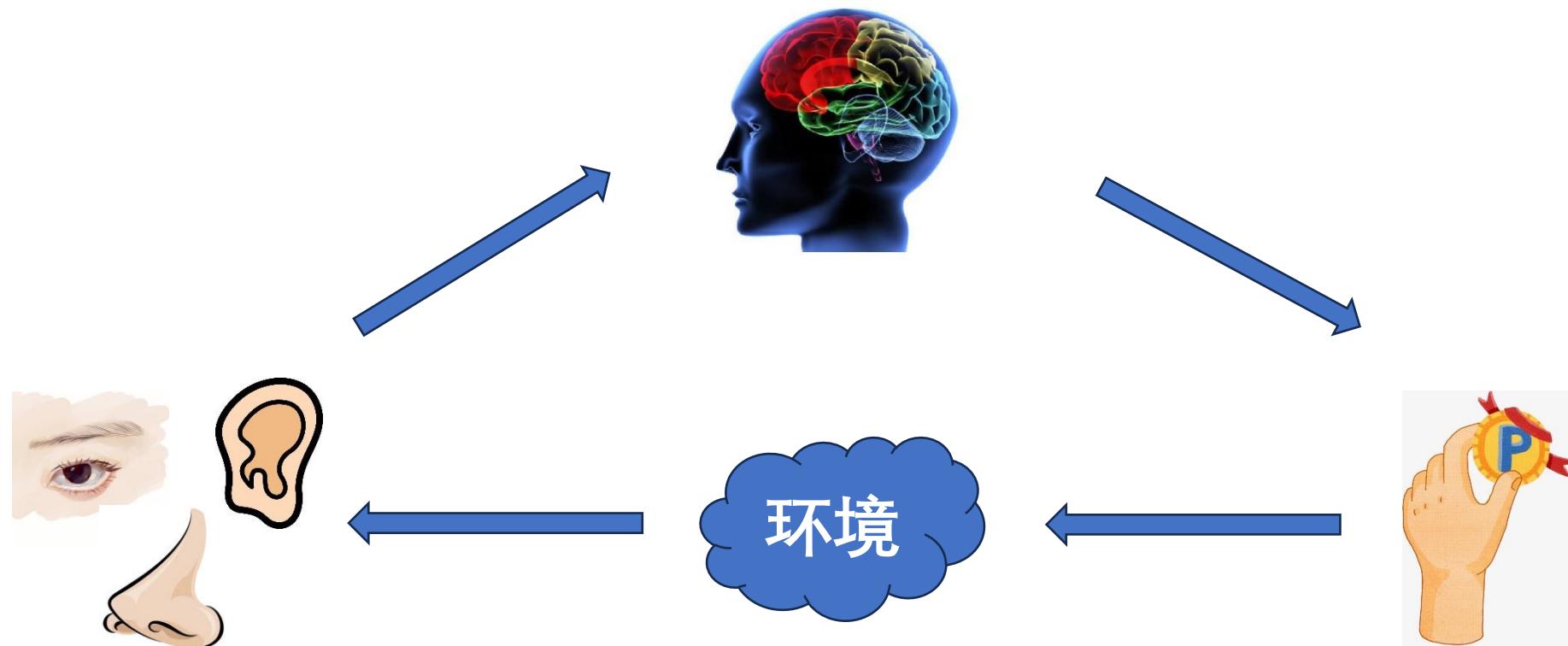


设计人工智能体



➤ 感知-动作回路才是认知的中心

一旦我们开始探索生物与环境之间的协调与交互，就很难再确定感知是什么时候结束的，而认知是什么时候开始的。



-
- 1 具身智能的背景
 - 2 具身智能的体系
 - 3 具身智能的关键技术
 - 4 具身智能的前沿发展

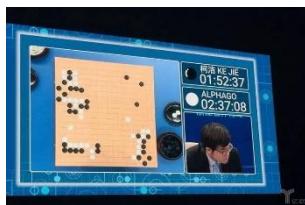
2 具身智能的体系

➤ 狹义与广义的具身智能



离身智能

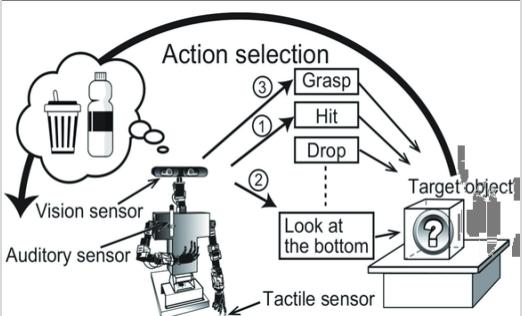
具身智能



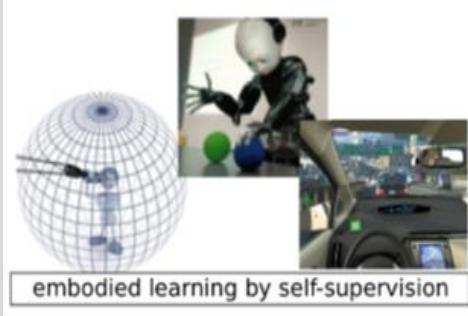
2 具身智能的体系

➤ 具身智能的典型任务

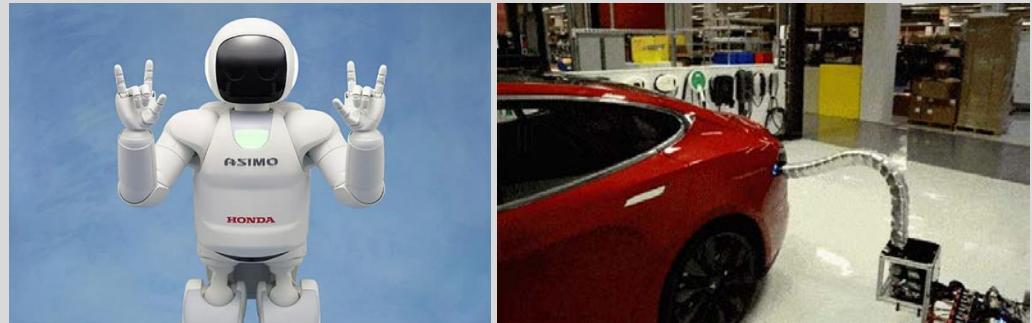
发现



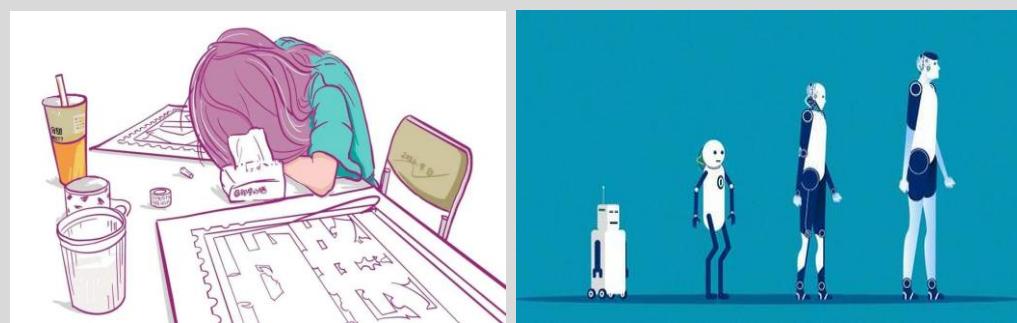
学习



控制



优化



具身智能

离身智能

2 具身智能的体系

➤ 具身智能与机器人的关系



2 具身智能的体系

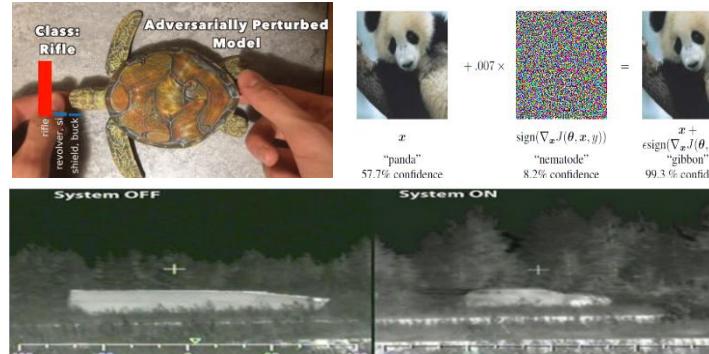
➤ 具身智能的优点、缺点与难点

Disembodied
Intelligence

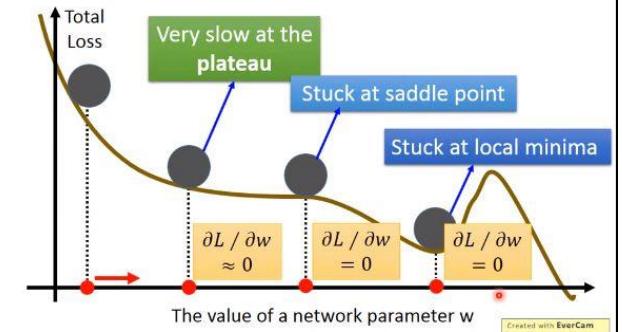
Good



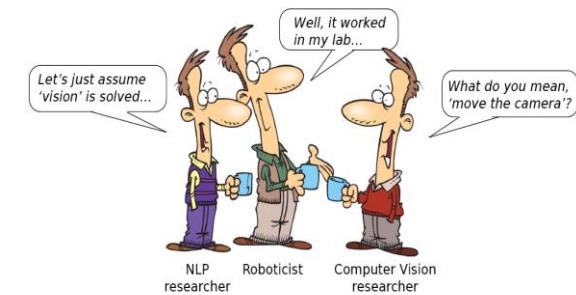
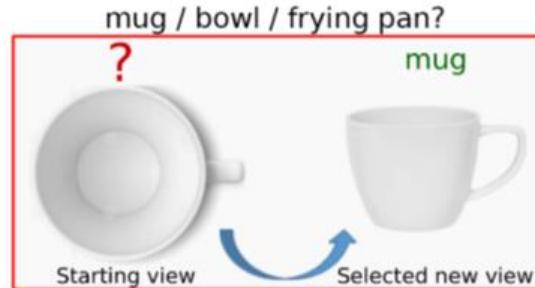
Bad



Ugly

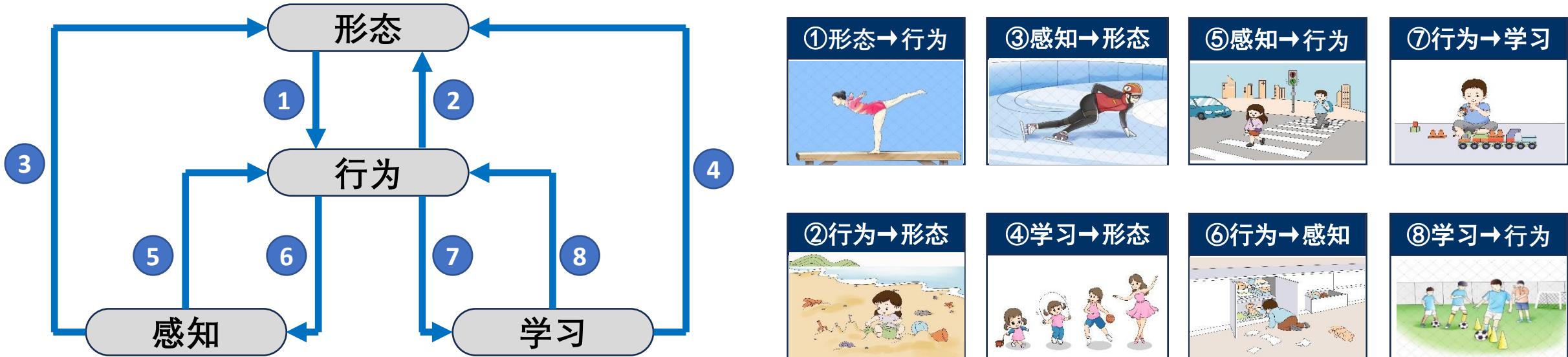


Embodied
Intelligence



2 具身智能的体系

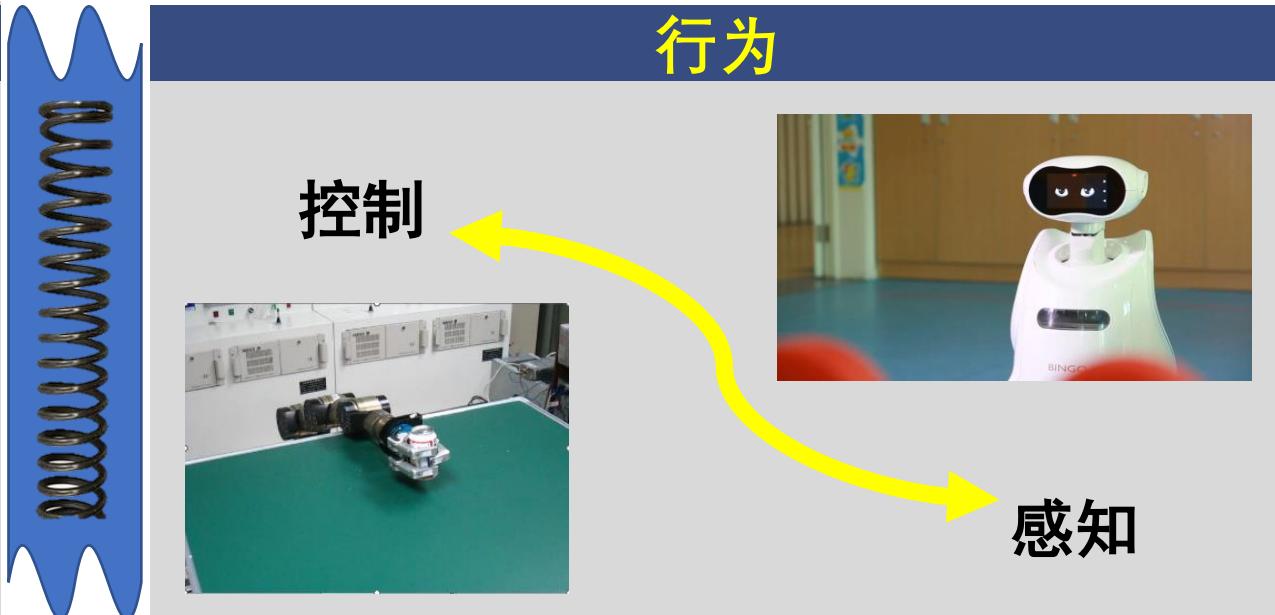
具身智能的体系结构



- ① 基于形态的行为生成
- ② 基于行为的形态控制
- ③ 基于感知的形态变换
- ④ 基于学习的形态优化
- ⑤ 基于感知的行为生成
- ⑥ 基于行为的主动感知
- ⑦ 基于行为的自主学习
- ⑧ 基于学习的行为优化

2 具身智能的体系

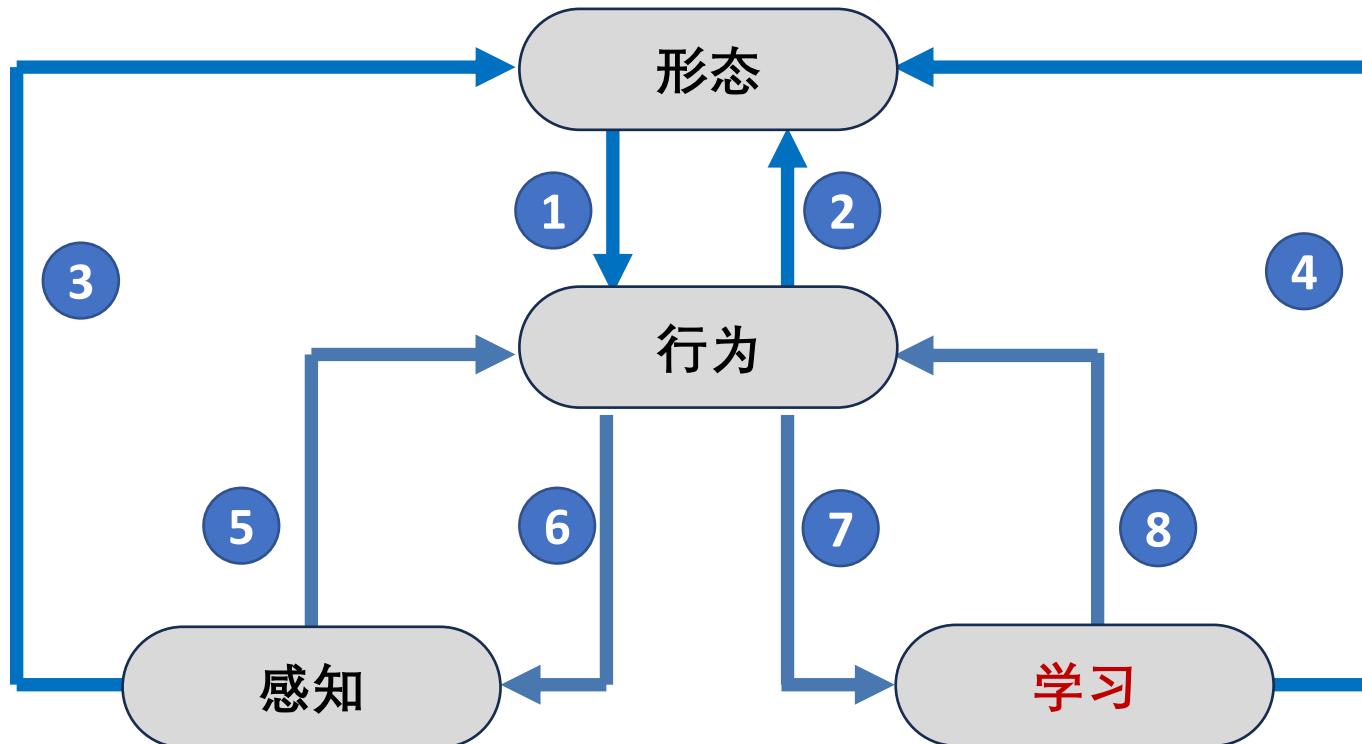
➤ 具身智能的体系结构



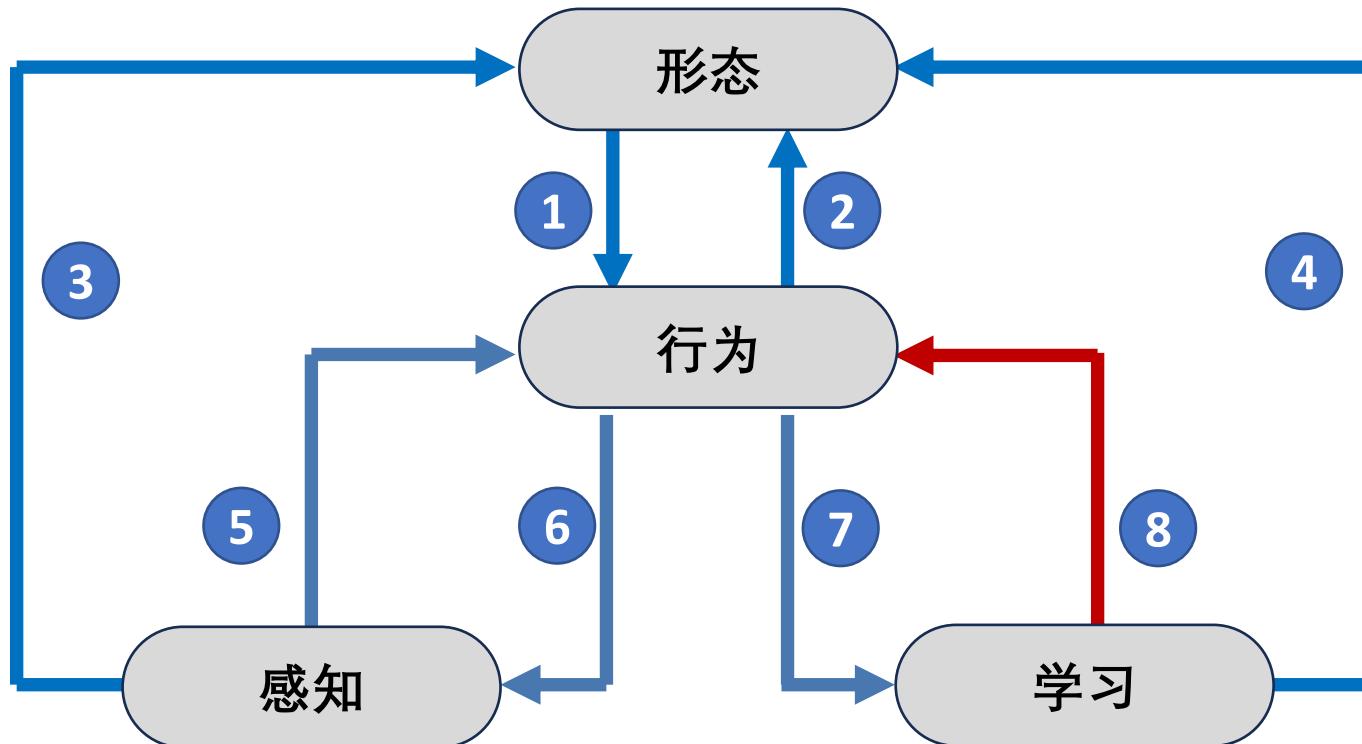
学习 \Rightarrow 大模型

-
- 1 具身智能的背景
 - 2 具身智能的体系
 - 3 具身智能的关键技术
 - 4 具身智能的前沿发展

3 关键技术



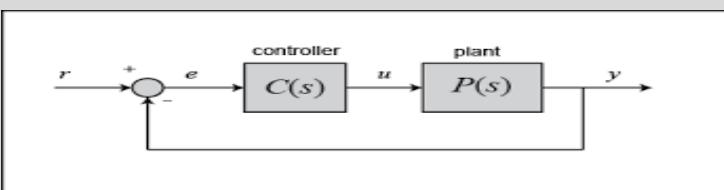
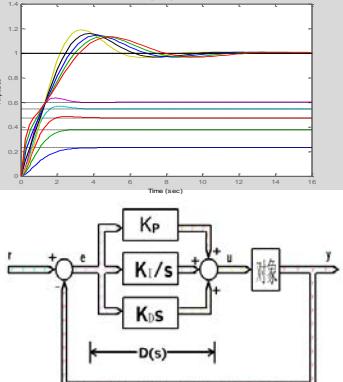
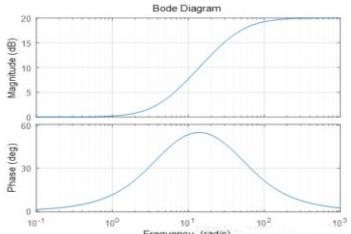
3 关键技术



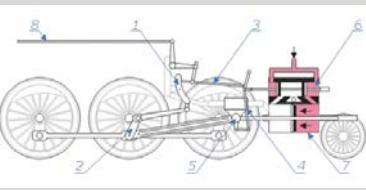
3.0 学习→行为：强化学习

经典控制：经验

$$G_c(s) = \frac{s + \frac{1}{T}}{s + \frac{1}{\alpha T}} \quad (\alpha < 1)$$



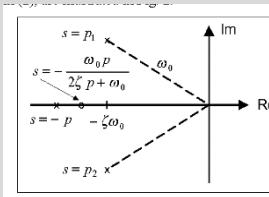
$$u_t = K_P e_t + K_I \int e_t dt + K_D \frac{de_t}{dt}$$



现代控制：模型

$$\begin{aligned} \text{state equations: } & \dot{x}_1 = f_1(x_1, x_2, \dots, x_n, u_1, \dots, u_m) \\ & \vdots \\ & \dot{x}_n = f_n(x_1, x_2, \dots, x_n, u_1, \dots, u_m) \\ \text{output equations: } & y_1 = h_1(x_1, x_2, \dots, x_n, u_1, \dots, u_m) \\ & \vdots \\ & y_p = h_p(x_1, x_2, \dots, x_n, u_1, \dots, u_m) \end{aligned}$$

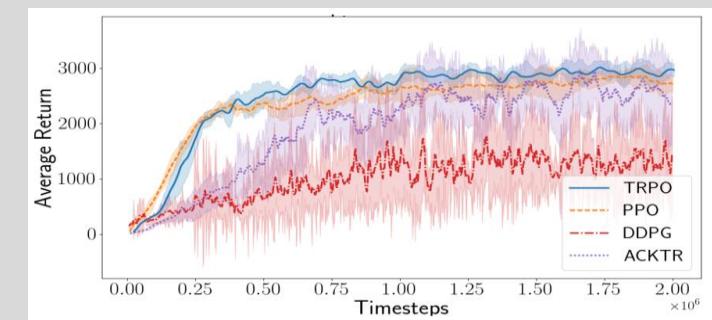
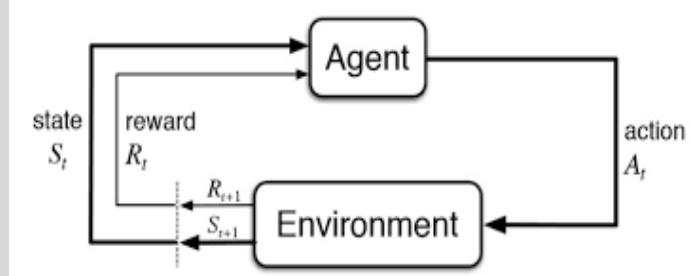
$$\begin{cases} \dot{x}_t = Ax_t + Bu_t \\ y_t = Cx_t + Du_t \end{cases}$$



$$u_t = -K x_t$$



智能控制：学习

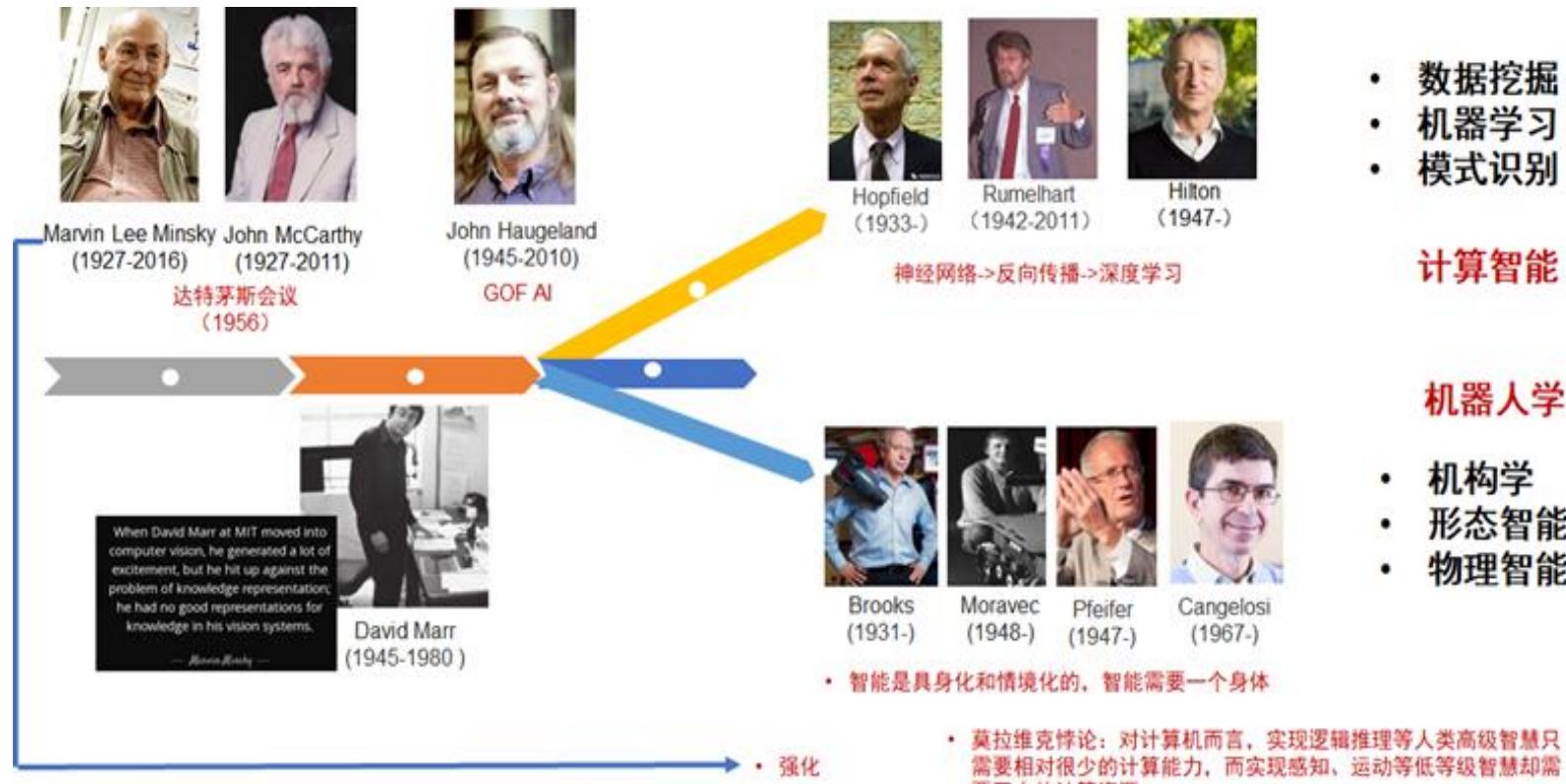


$$\pi_{\theta}(a_t | s_t)$$



3.0 学习→行为：强化学习

➤ 起源



人工神经网络
Artificial Neural Networks

Walter Pitts, 1943



深度学习
Deep Learning

Geoffrey Hinton, 2006



深度强化学习
DQN

DeepMind, 2015

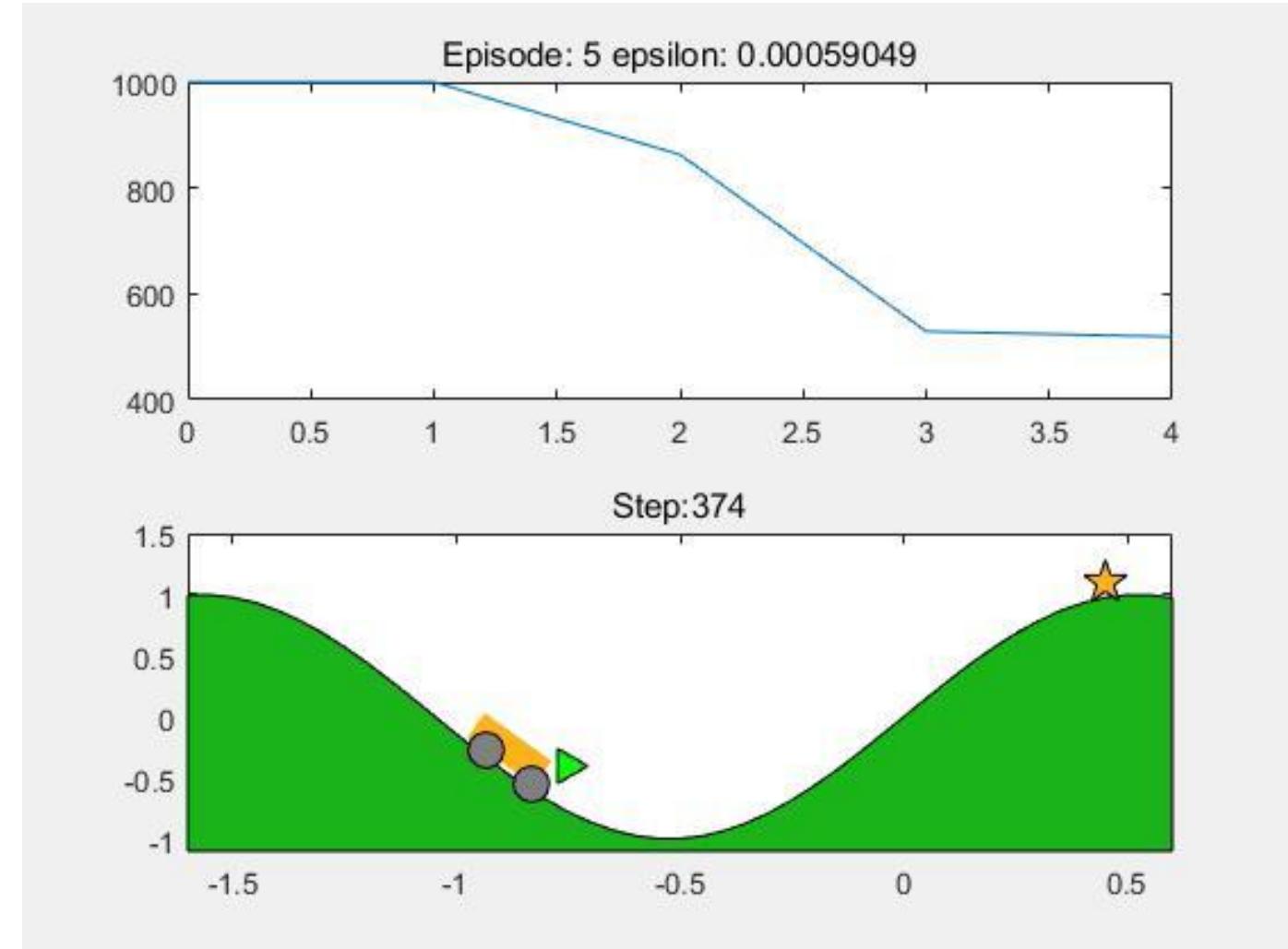
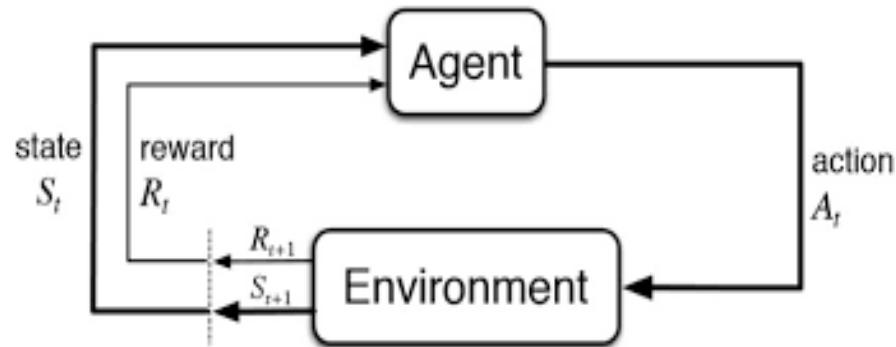
最优控制与动态规划
Markov Decision Process

Richard Bellman, 1957

时序差分与最优控制
Q-learning

Chris Watkins, 1989

3.0 学习→行为：强化学习



3.0 学习→行为：强化学习

➤ 两类基本算法

Q-学习算法

$$\max_{\theta} \mathbb{E} \left[\sum_{t=0}^H R(s_t) | \pi_{\theta} \right]$$

$$Q(s_t, a_t) = r_{t+1} + \gamma r_{t+2} + \gamma^2 r_{t+3} + \gamma^3 r_{t+4} + \dots$$

$$Q(s_t, a_t) = r_{t+1} + \gamma Q(s_{t+1}, a_{t+1})$$

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha [r + \gamma \max_a Q(s_{t+1}, a) - Q(s_t, a_t)]$$

$$\pi^*(s) = \arg \max_{a \in \mathcal{A}} Q^*(s, a)$$

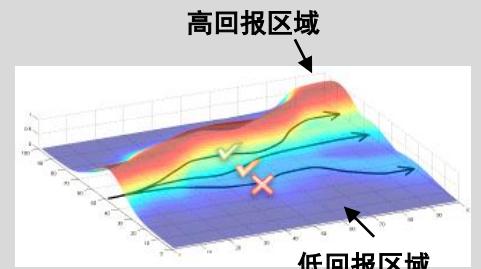


发展：DQN

策略梯度算法

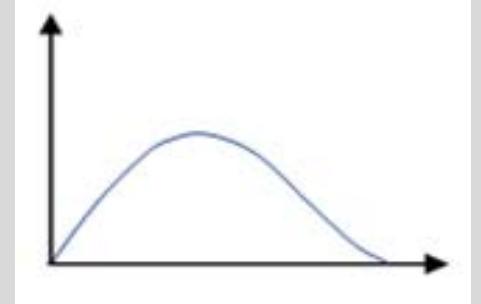
$$J(\pi) = \mathbb{E}_{\tau \sim p_{\pi}(\tau)} \left[\sum_{t=0}^{\infty} \gamma^t r(s_t, a_t, s_{t+1}) \right]$$

$$\nabla_{\theta} J(\pi_{\theta}) \approx \frac{1}{N} \sum_{n=1}^N \sum_{t=0}^{H^{(n)}} R(\tau^{(n)}) \nabla_{\theta} \log \pi_{\theta}(a_t^{(n)} | s_t^{(n)})$$



$$\theta \leftarrow \theta + \eta \nabla_{\theta} J$$

$$\pi_{\theta}(a | s)$$



发展：REINFORCE

3.0 学习→行为：强化学习

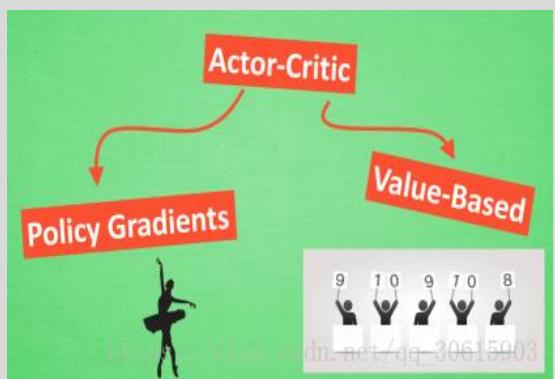
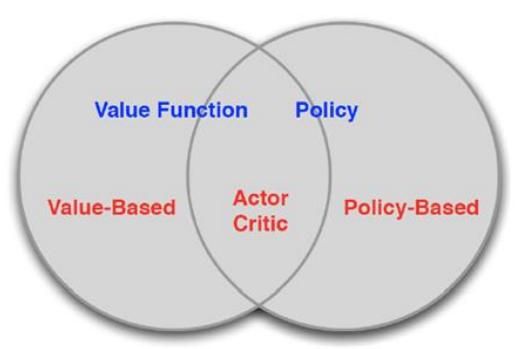
➤ 两类典型算法

Actor-Critic

$$\nabla_{\theta} J(\pi_{\theta}) = \mathbb{E}_{s \sim p_0(s)} \mathbb{E}_{a \sim \pi_{\theta}(\cdot|s)} (Q^{\pi_{\theta}}(s, a) \cdot \nabla_{\theta} \log \pi_{\theta}(a | s))$$

$$\hat{Q}_{\omega}(s, a) \approx Q^{\pi_{\theta}}(s, a)$$

$$\nabla_{\theta} J(\pi_{\theta}) = \hat{Q}_{\omega}(s_t, a_t) \cdot \nabla_{\theta} \log \pi_{\theta}(a_t | s_t)$$



PPO

$$A^{\pi_{\theta}}(s_t, a_t) = Q^{\pi_{\theta}}(s_t, a_t) - V^{\pi_{\theta}}(s_t)$$

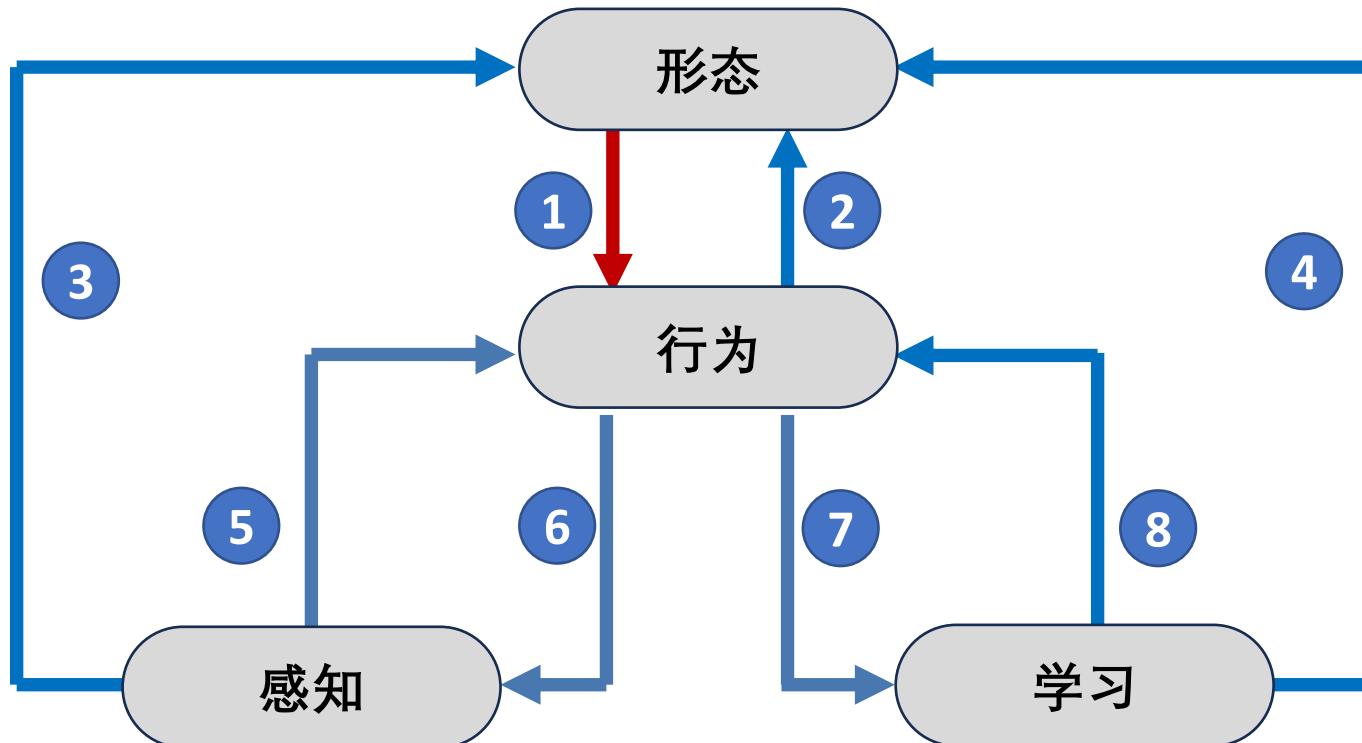
$$\mathbb{E}_{\tau \sim p_{\pi_{\theta}}(\tau)} \left(\sum_{t=0}^{\infty} \gamma^t A^{\pi_{\theta_{\text{old}}}}(s_t, a_t) \right)$$

$$L_{\pi_{\theta_{\text{old}}}}(\pi_{\theta}) = \mathbb{E}_{\tau \sim p_{\pi_{\theta_{\text{old}}}(\tau)}} \left(\sum_{t=0}^{\infty} \gamma^t \rho_t(\theta) A^{\pi_{\theta_{\text{old}}}}(s_t, a_t) \right)$$

$$L_{\pi_{\theta_{\text{old}}}}(\pi_{\theta}) = \mathbb{E}_{\tau \sim p_{\pi_{\theta_{\text{old}}}(\tau)}} \left(\sum_{t=0}^{\infty} \gamma^t \min \left\{ (\rho_t(\theta) A^{\pi_{\theta_{\text{old}}}}(s_t, a_t), \text{clip}(\rho_t(\theta), 1-\varepsilon, 1+\varepsilon) A^{\pi_{\theta_{\text{old}}}}(s_t, a_t)) \right\} \right)$$

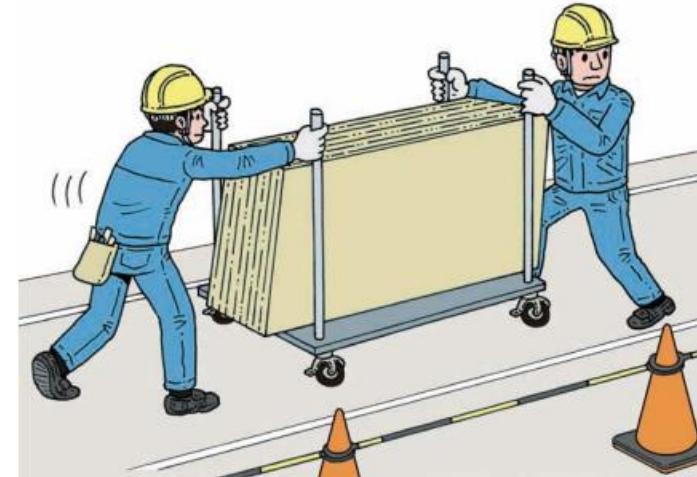
$$\text{clip}(\rho_t(\theta), 1-\varepsilon, 1+\varepsilon) = \begin{cases} \rho_t(\theta) & 1-\varepsilon \leq \rho_t(\theta) \leq 1+\varepsilon \\ 1-\varepsilon & \rho_t(\theta) < 1-\varepsilon \\ 1+\varepsilon & \rho_t(\theta) > 1+\varepsilon \end{cases}$$

3.1 形态→行为



3.1 形态→行为

➤ 例子



3.1 形态→行为

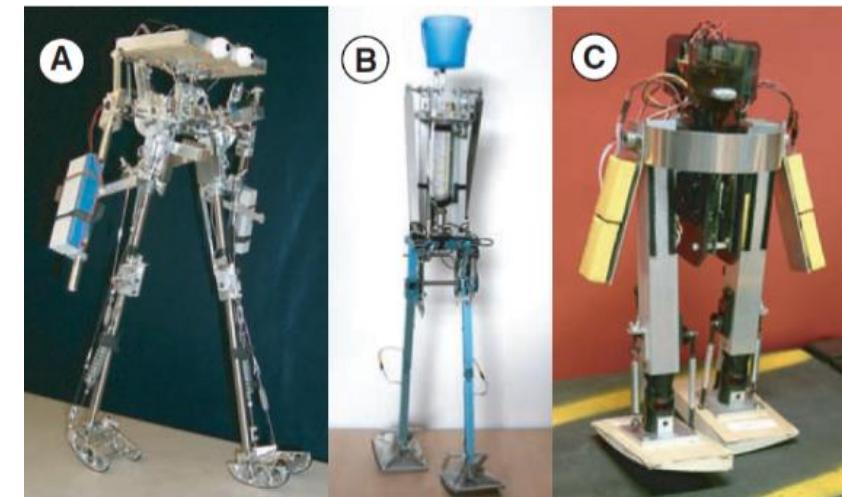
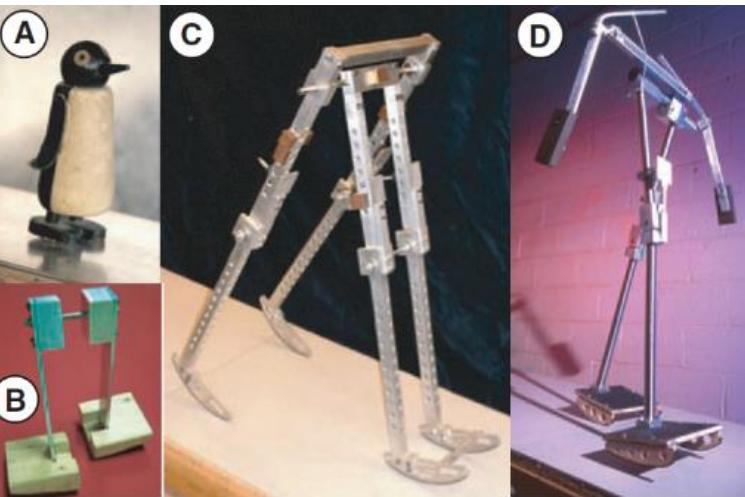
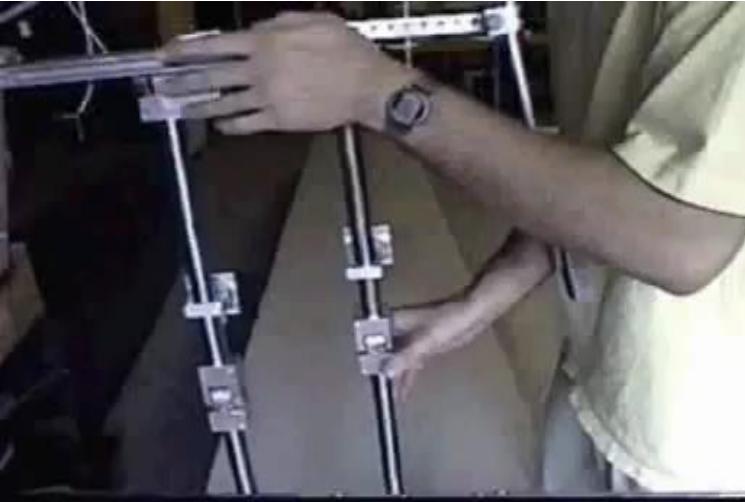
➤ 边界

由于形态计算方面的研究与仿生机器人的研究关系非常密切，二者之间的关系会引起混淆。事实上，形态计算更关心的是利用形态来产生行为，而并非从形态上简单地模仿某些生物。很多仿生型机器人，只是形体上模仿了动物的身体，这种模仿可能能获得一些自由度上的突破，例如腿式机器人相比轮式能爬楼，但在行为控制方面，并没有充分利用形态自身的优势，而且仍需要设计复杂的控制器。本田的Asimo机器人，尽管已经充分接近人类的外形，但其每一个关节都需要用特定的算法来控制。这些情形都不属于形态计算之列。

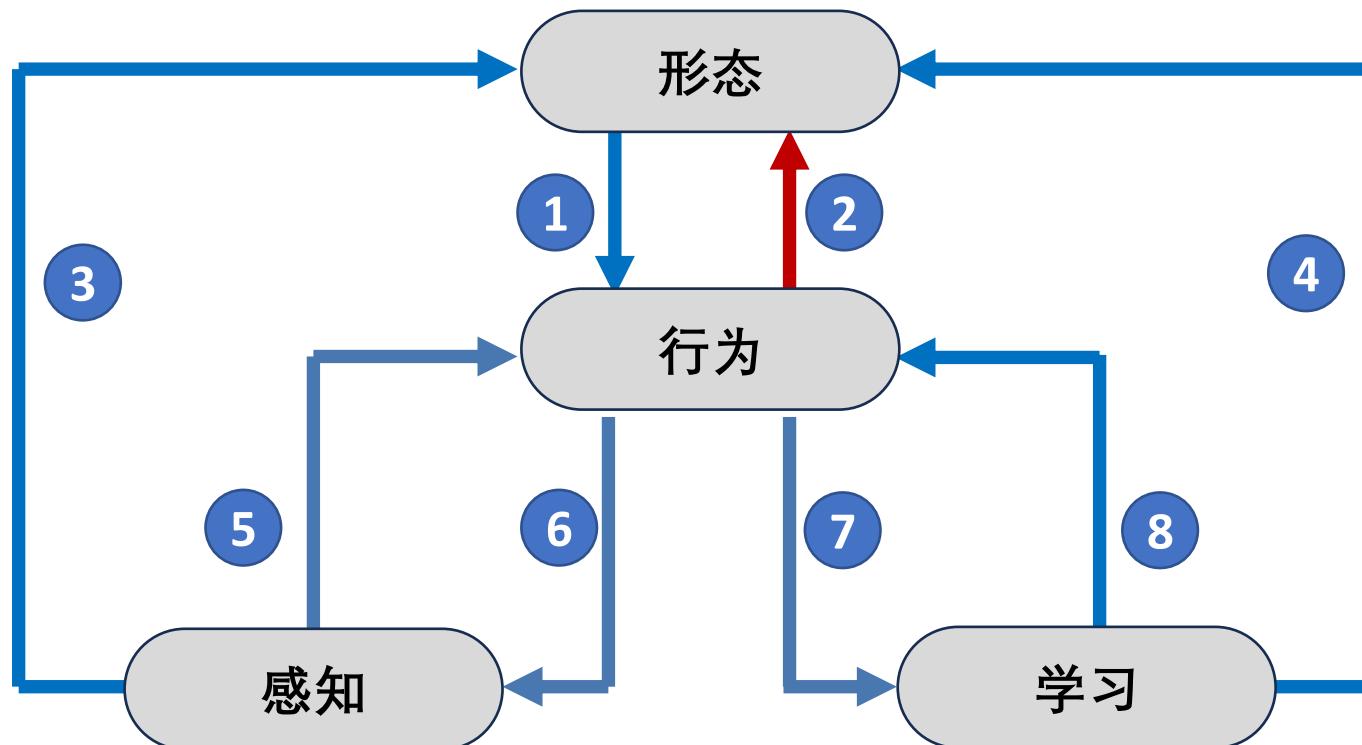


3.1 形态→行为

➤ 被动行走机器人 (Passive Walking Robot)



3.2 行为→形态：形态控制



3. 2 行为→形态：形态控制

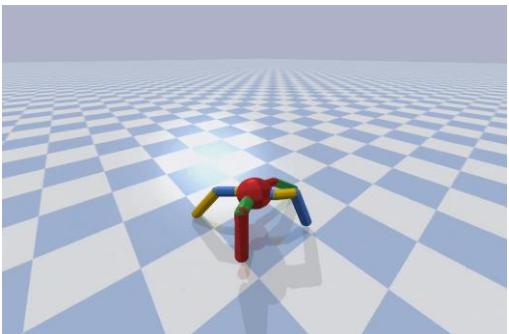
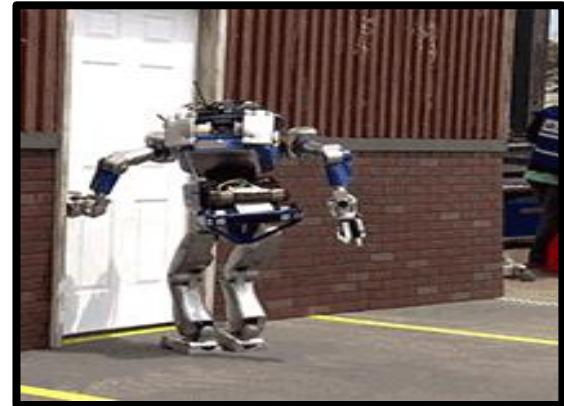
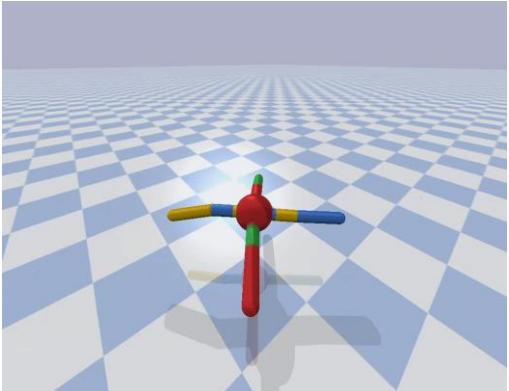
➤ 形态约束



3. 2 行为→形态：形态控制

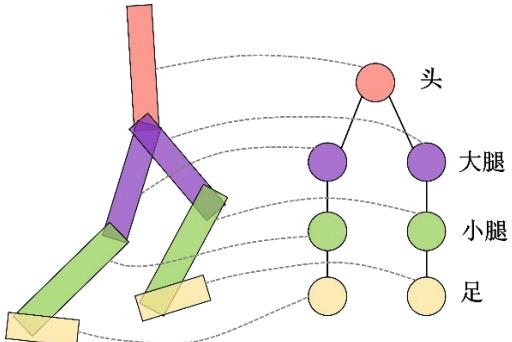
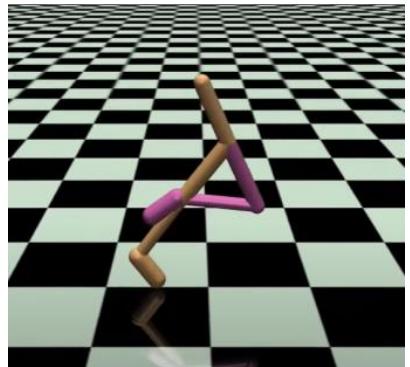
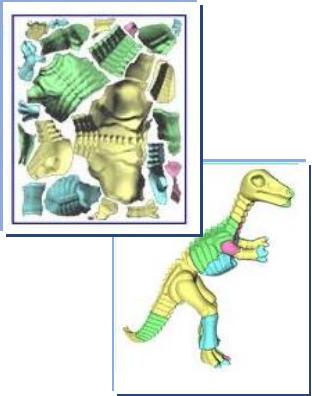
➤ 强化学习的维数灾

- 机器人自由度多，优化学习困难
- 机器人形态**复杂**，难以利用
- 在不同形态之间的**迁移**



3. 2 行为→形态：形态控制

➤ 引入结构性约束



$$\pi_{\theta}(a_t \mid s_t)$$

图结构表示

$$D = (V, E, Y)$$

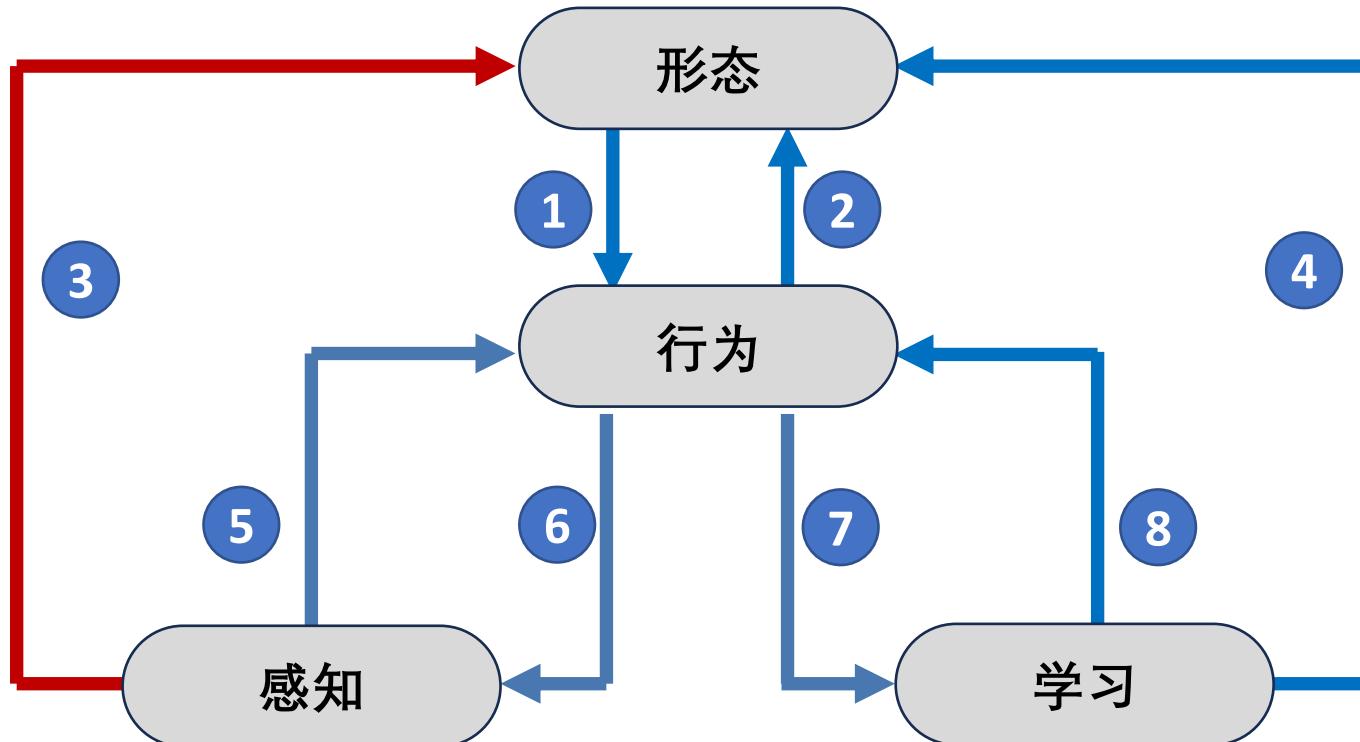
$N_{out}(v)$ 所有以 v 作为头节点的有向边所指向的尾节点的集合。这一集合反映的是节点 v 的“输出节点”。

$N_{in}(v)$ 所有以 v 作为尾节点的边的头结点的集合。这一集合反映的是节点 v 的“输入节点”。

$$Y_V(v_i) \in \{1, 2, \dots, |Y_V|\}$$

$$Y_E(\{v_i, v_j\}) \in \{1, 2, \dots, |Y_E|\}$$

3. 3 感知→形态：形态变换



3. 3 感知→形态：形态变换



3. 3 感知→形态：形态变换

➤ 地形适应的形态变换

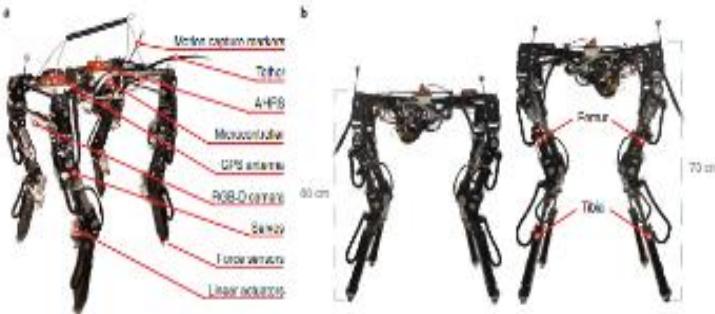
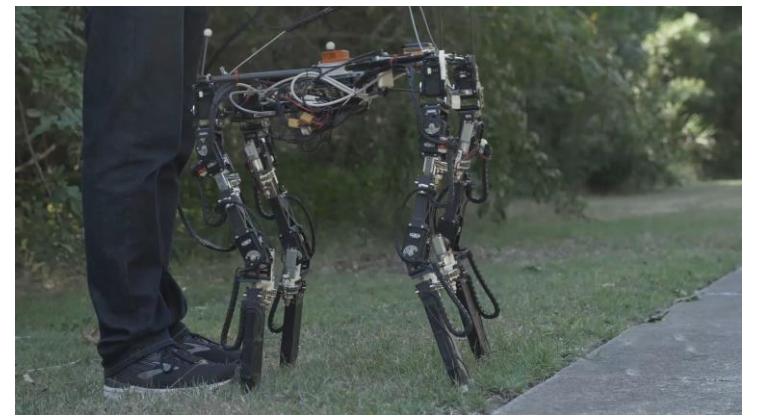
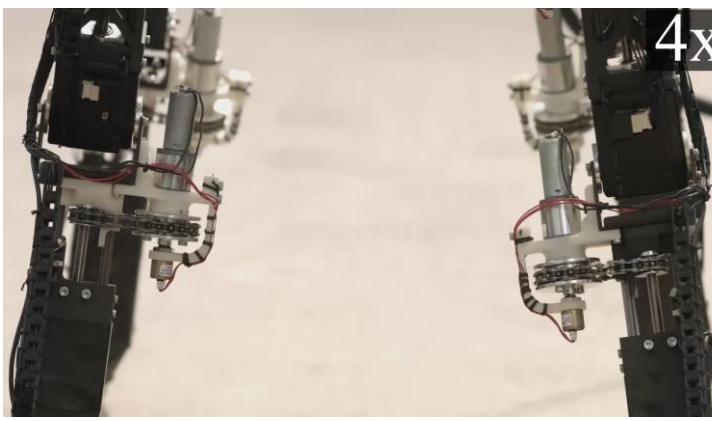
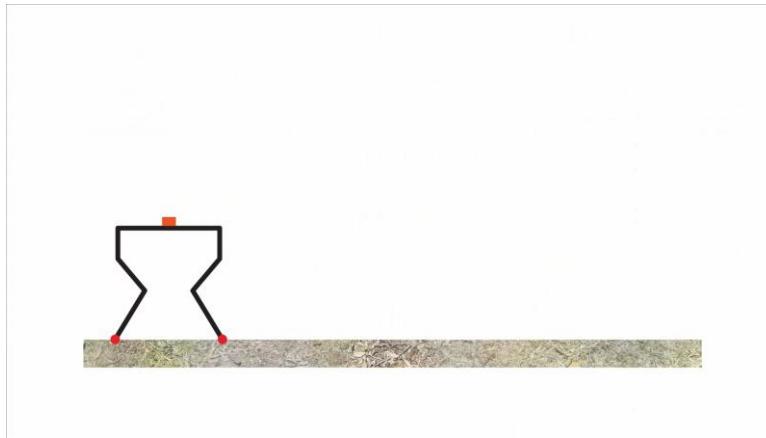


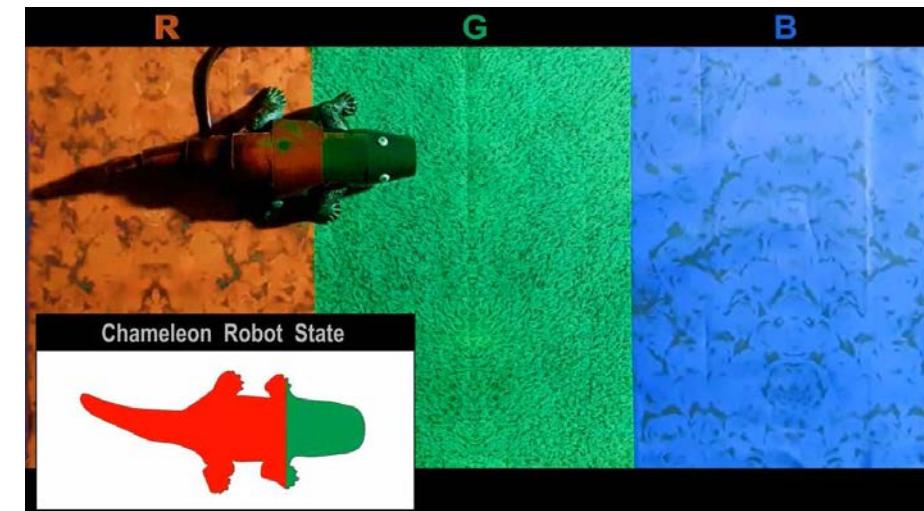
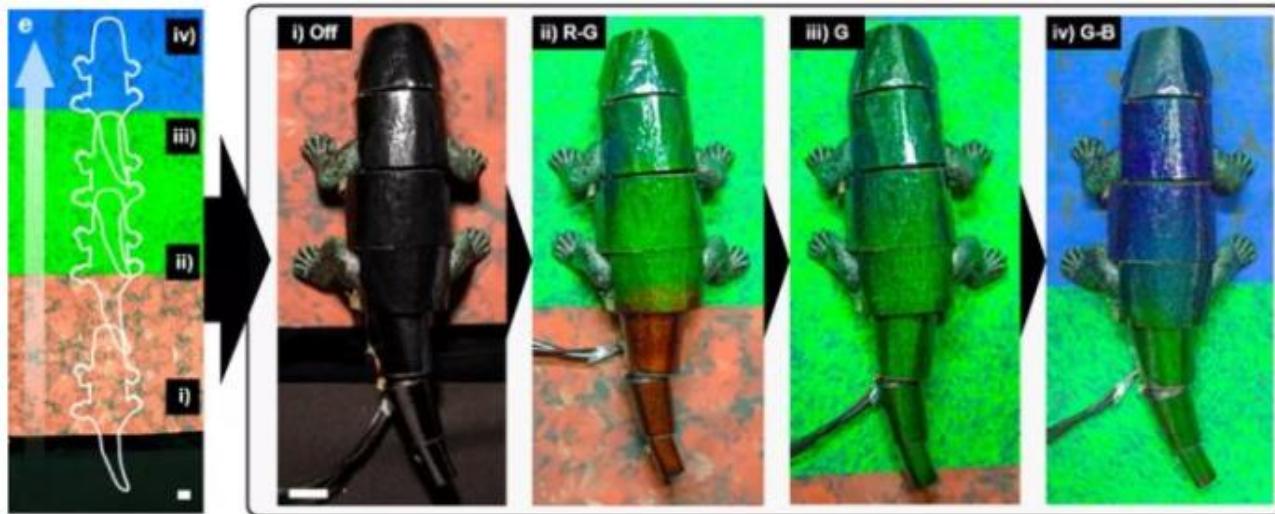
Fig. 1 | The morphologically adaptive robot used in this study. a, An overview of the main components of the robot. b, The robot with the shortest (left) and longest (right) leg configuration. AHRS, attitude and heading reference system; GPS, global positioning system; RGB-D, red, green, blue and depth.



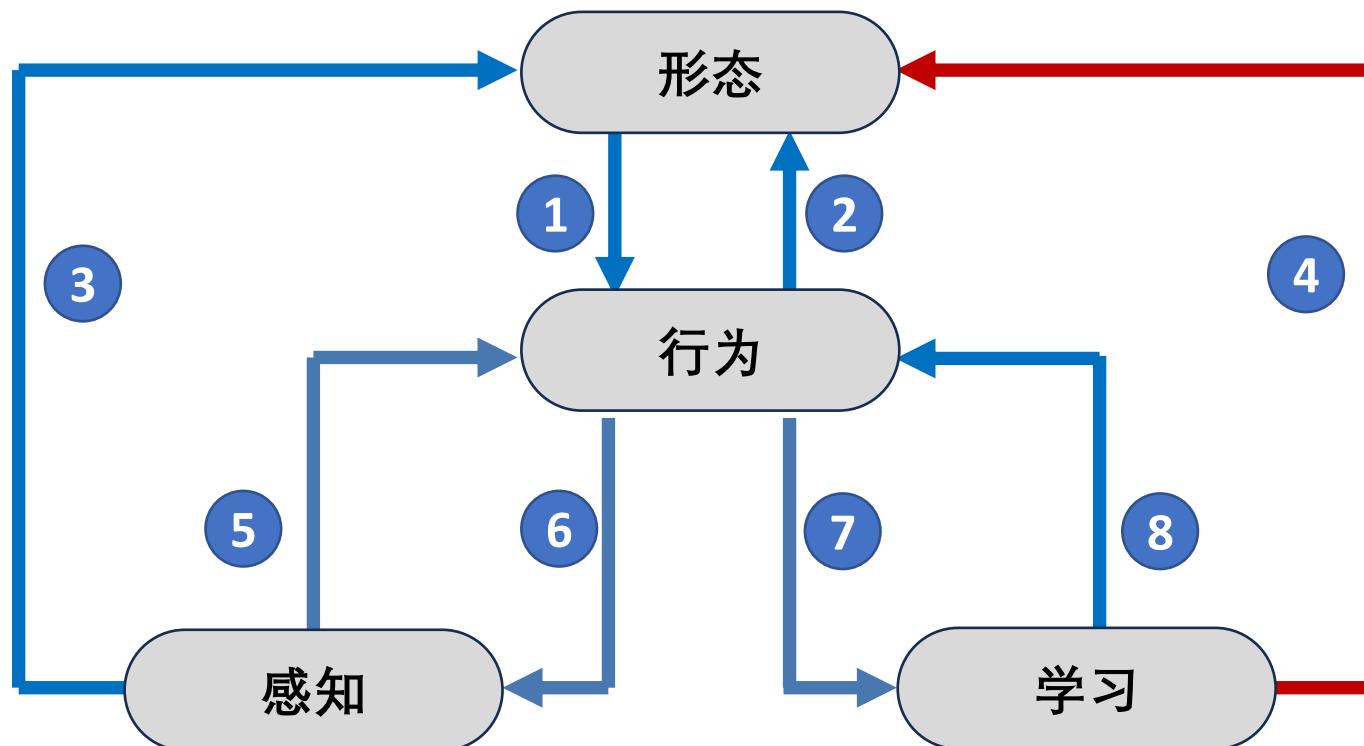
3. 3 感知→形态：形态变换

➤ 仿变色龙软体机器人

将人造变色龙皮肤应用于软体机器人上，并结合颜色传感器和反馈控制系统，从而使得这种设备级的自适应人造伪装技术能够检测到背景环境的颜色，并令变色龙软体机器人上实现实时背景颜色匹配。

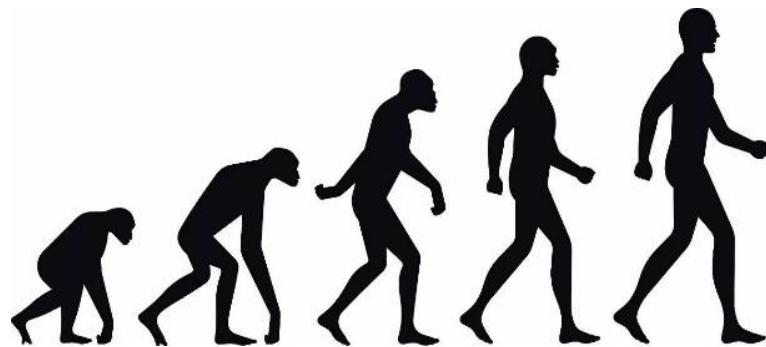


3.4 学习→形态：形态生成



3.4 学习→形态：形态生成

➤ 脑-体协同进化

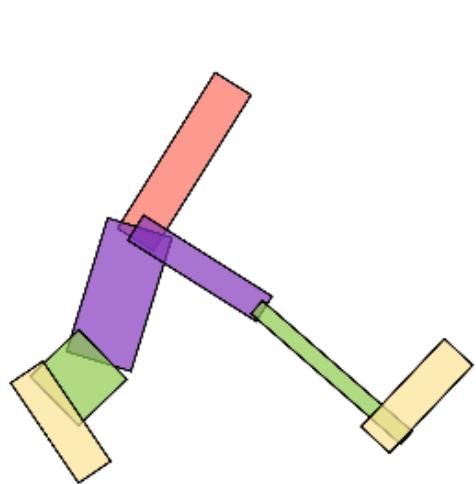


$$(D^*, \pi^*) = \arg \max_{D, \pi} J(D, \pi)$$

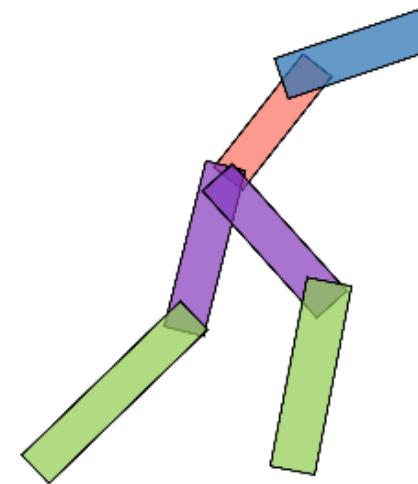
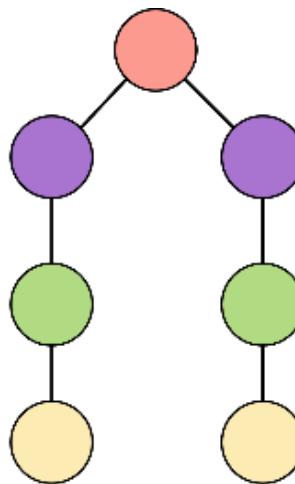
$$\pi^* = \arg \max_{\pi} J(\bar{D}, \pi)$$

3.4 学习→形态：形态生成

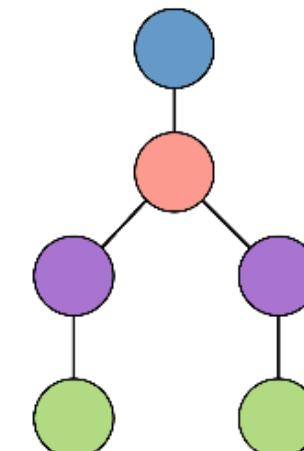
➤ 脑-体协同进化



形态参数

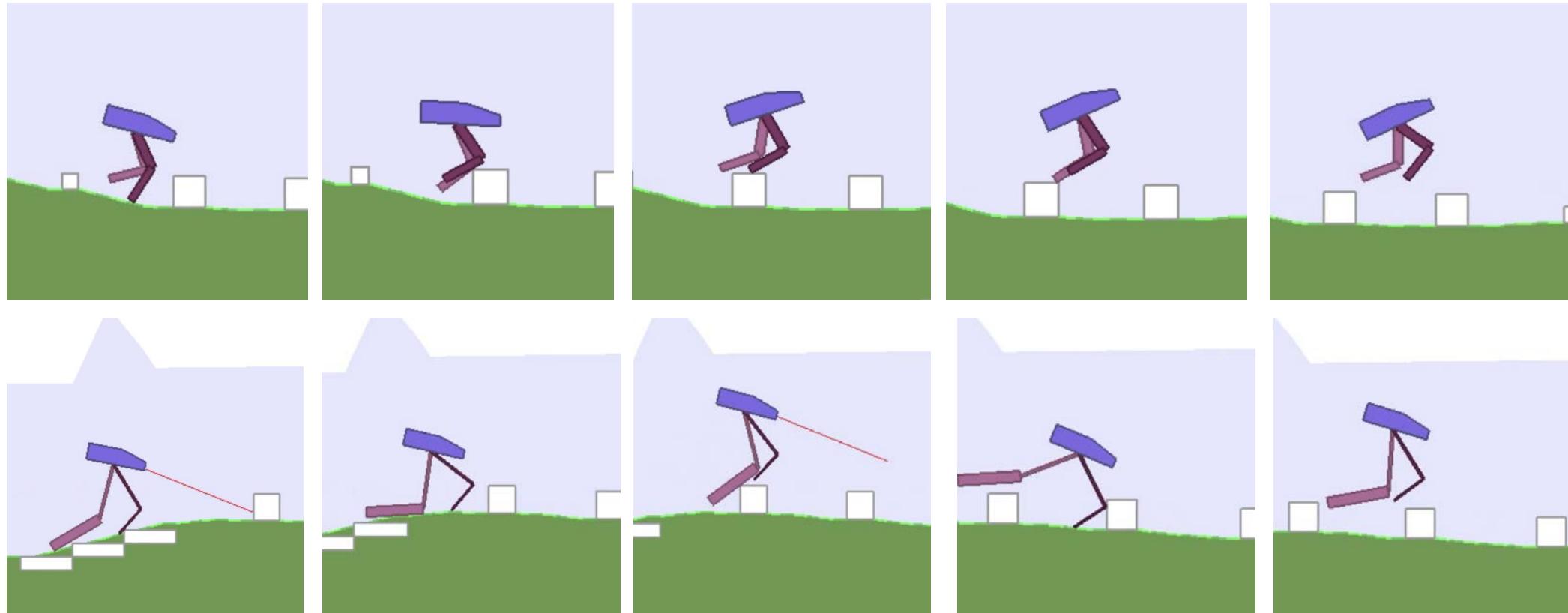


形态结构

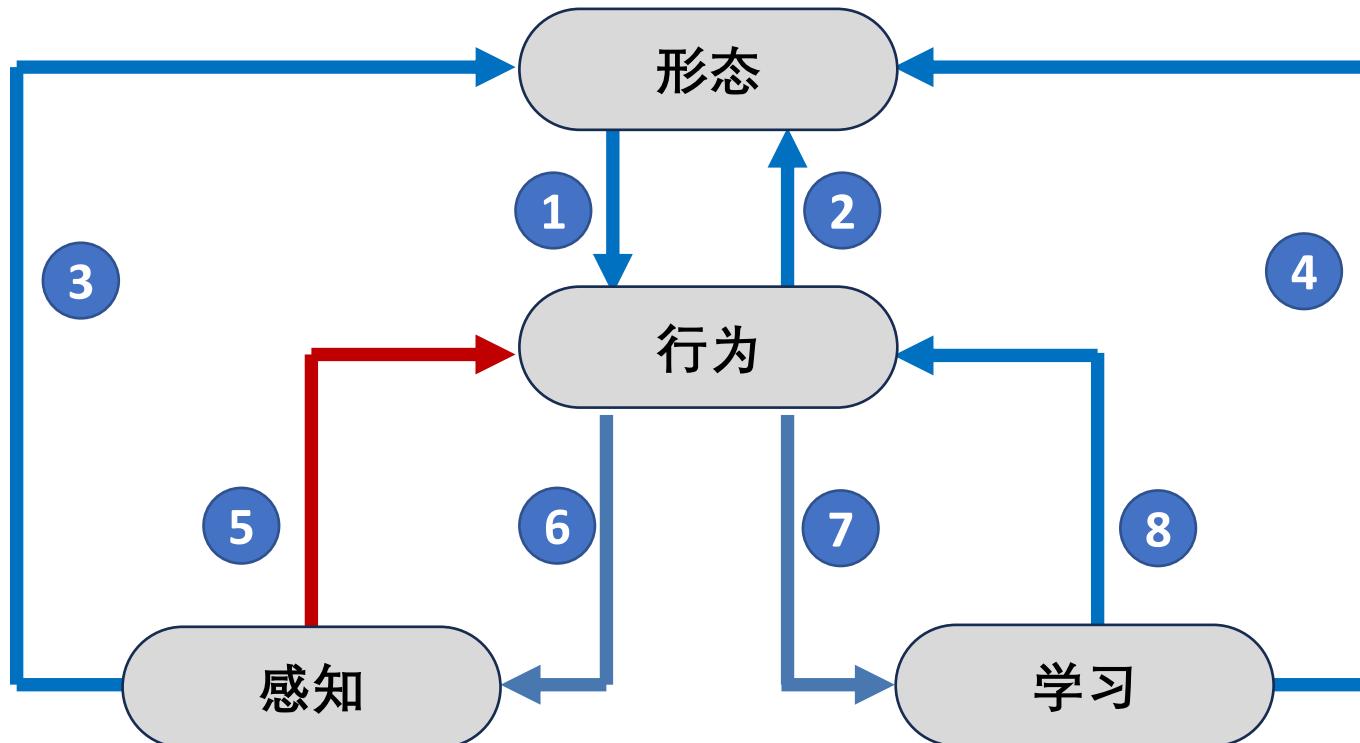


3.4 学习→形态：形态生成

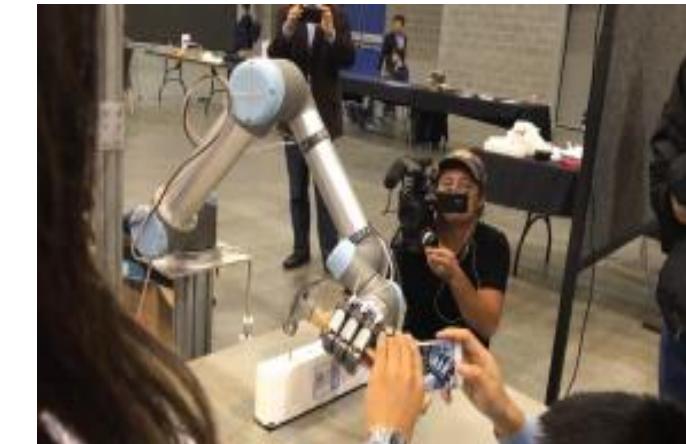
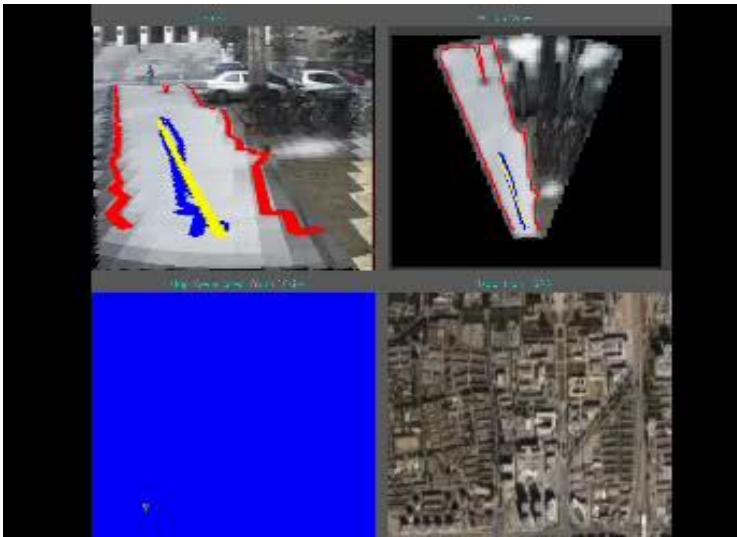
➤ 形态参数的优化



3.5 感知→行为：视觉导航

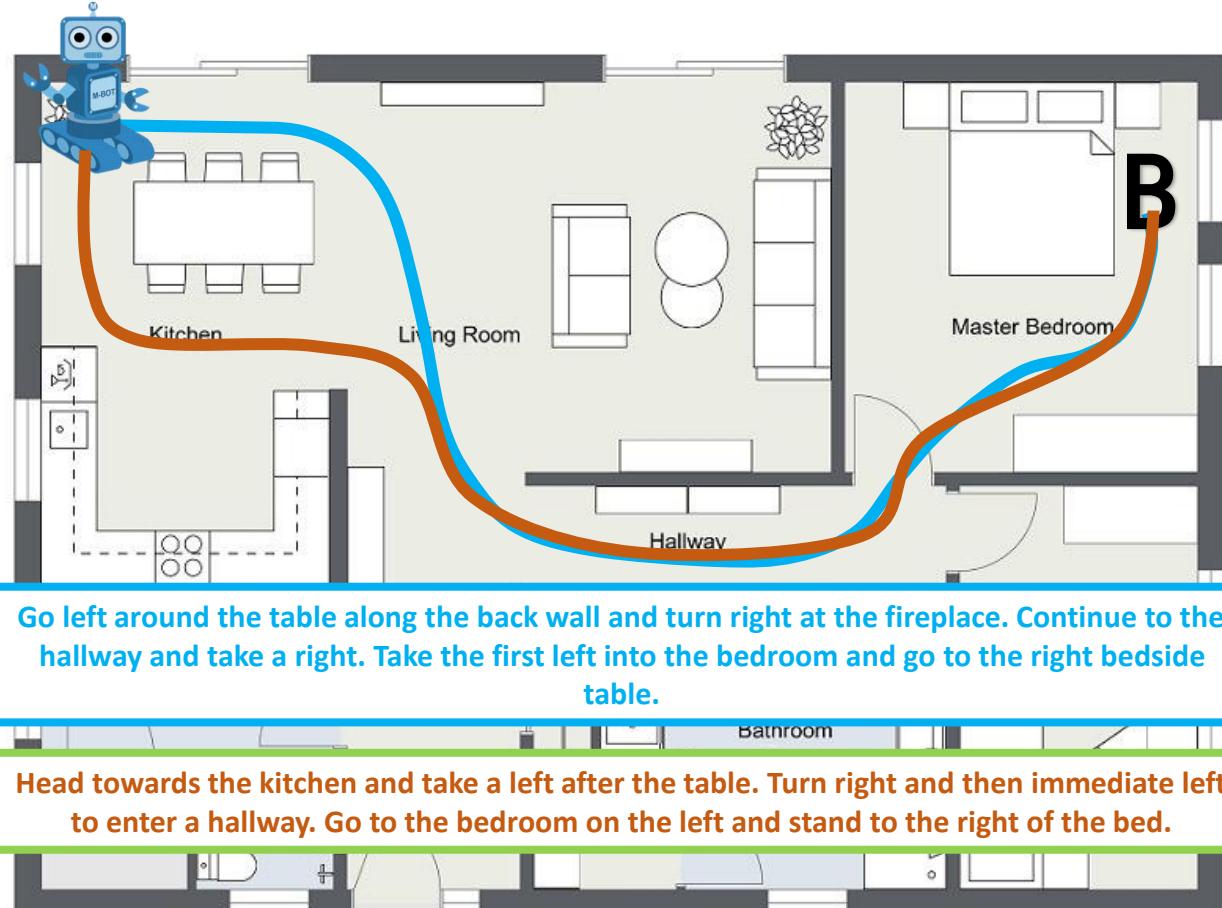


3. 5 感知→行为：视觉导航



3. 5 感知→行为：视觉导航

➤ 视觉语言导航

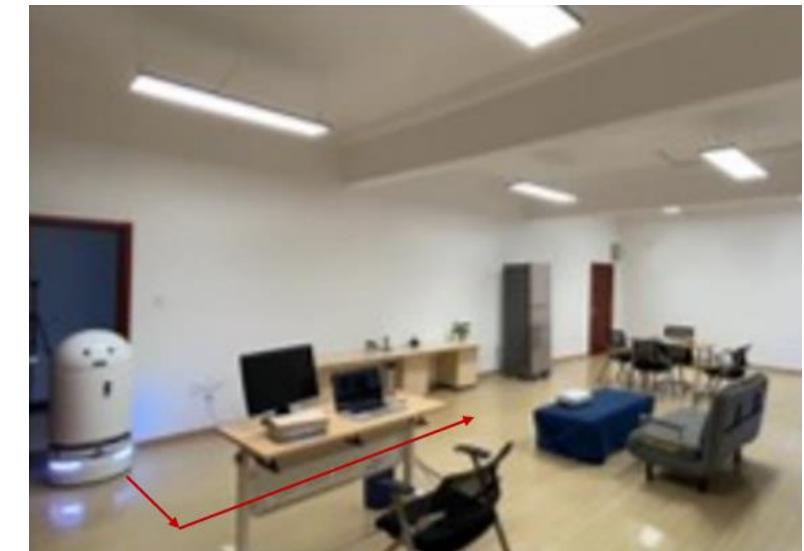
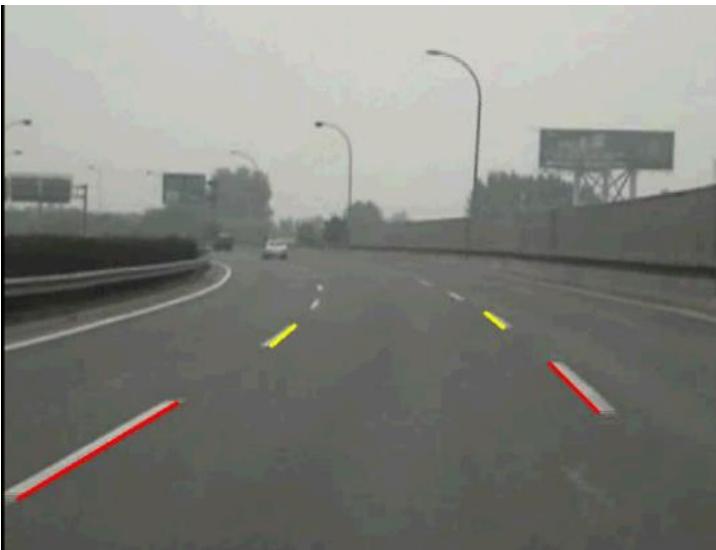


- Vision language navigation (VLN) 让智能体跟着自然语言指令进行导航，这个任务需要同时理解自然语言指令与视角中可以看见的图像信息，然后在环境中对自身所处状态做出对应的动作，最终达到目标位置。



3. 5 感知→行为：视觉导航

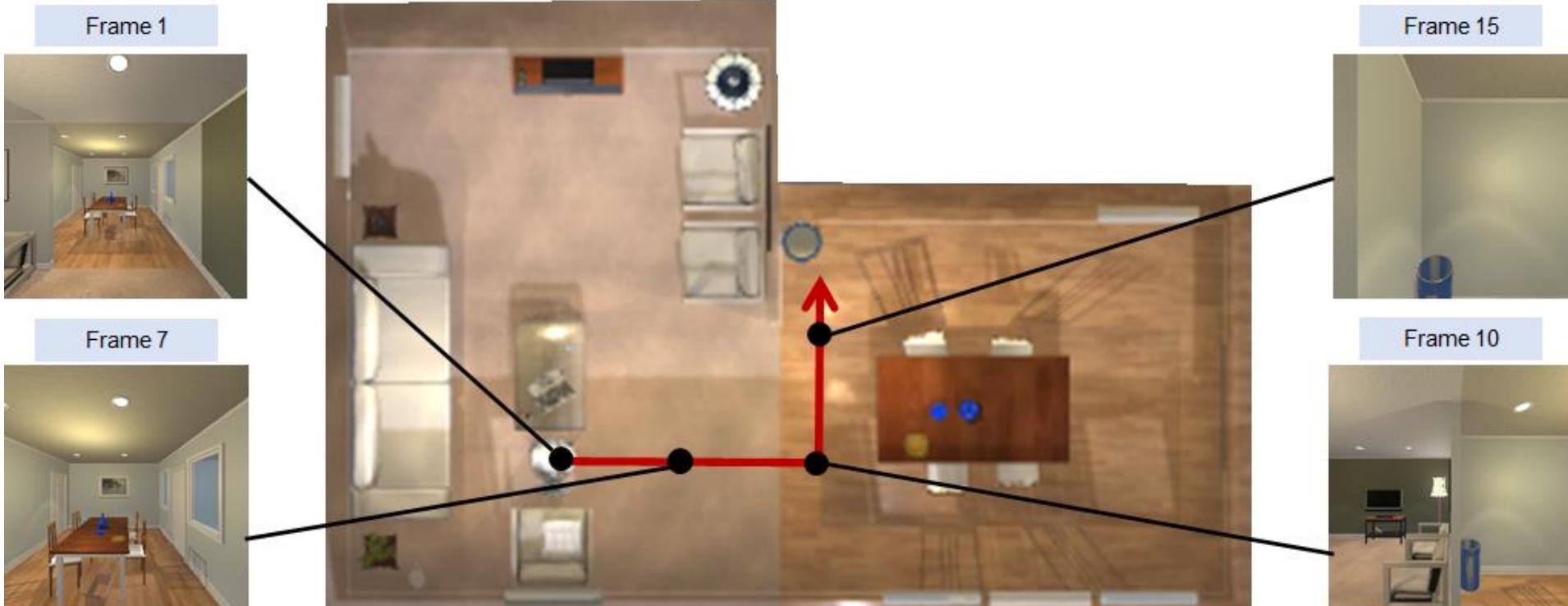
➤ 视觉语言导航



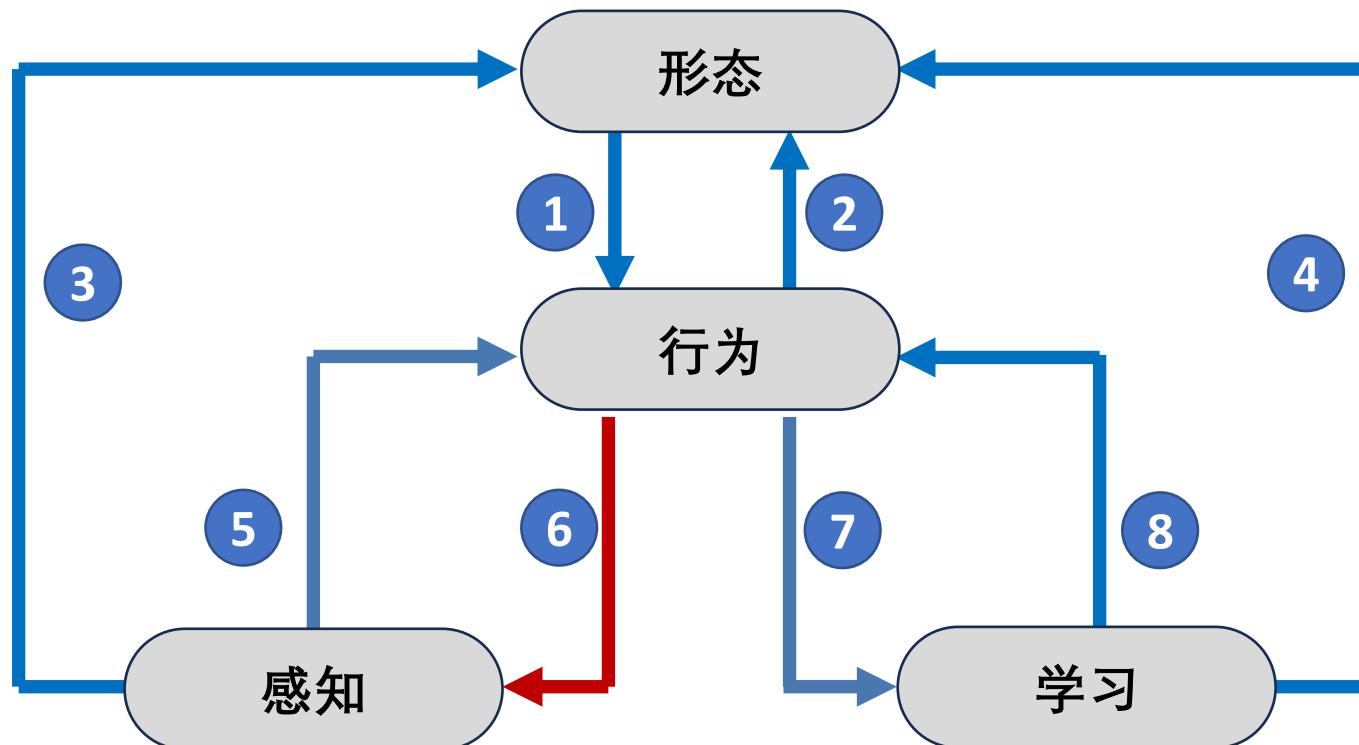
3. 5 感知→行为：视觉导航

➤ 问题描述

语言指令：Walk a few steps straight, and then turn to left
and move several steps left to the garbage can on right.



3.6 行为→感知：主动感知



3.6 行为→感知：主动感知

➤ 生活中的主动感知



3.6 行为→感知：主动感知

➤ 主动感知的应用



3.6 行为→感知：主动感知

➤ 主动感知的优点

- A motivation for examining active vision is the fact that passive vision has been shown to be very problematic.
- Almost every basic problem in passive machine perception is very difficult, it is ill-posed in the sense of Hadamard.
- Problems that are **ill-posed**, **nonlinear** or **unstable** for a passive observer become **well-posed**, **linear** or **stable** for an active observer.



Active Perception

RUZENA BAJCSY, MEMBER, IEEE
Invited Paper

Active Perception (Active Vision) specifically is defined as a study of the interaction between the sensor, processing modules and their interaction with the environment. It is concerned with the active sensing process, the extent of application in space and time. The local models represent the sensor and the global models represent the environment. The global models on the other hand characterize the overall performance of the system. Active perception is concerned with the development of control strategies as formulated as a search of such sequence of steps that will yield the maximum amount of information about the environment. Examples are shown as the existence proof of the proposed theory in other range from focus and stereovision to depth perception. A 2-D and 3-D example is shown for the first time.

B. What is Active Perception?
In the robotics and computer vision literature, the term "active sensor" generally refers to a sensor that transmits (generally electromagnetic radiation, e.g., radar, sonar, ultrasound, microwaves and collimated light) into the environment and receives and measures the reflected signals. We believe that this definition is too narrow. A necessary condition on active sensing, and that sensing can be performed with passive sensors (that only receive, and do not transmit), is that the sensor is able to move. We prefer to denote active not to denote a time-of-flight sensor, but to denote a passive sensor employed in an active fashion, purposefully changing the sensor's state parameters according to sensing strategy.

Hence the problem of Active Sensing can be stated as a problem of control strategies applied to the data acquisition process which determines the context of the data, the data interpretation and the goal or the task of the process. The question may be asked, "Is Active Sensing only an application of the well-known sensor fusion?" The answer is: "No, at least not in its simplest version." Here is why:

- 1) The feedback is performed not only on sensory data, but on complex processed sensory data, i.e., various extracted features, including relational features.
- 2) The sensor is not a simple sensor, but a sensor-augmented model that is a mixture of numeric/parametric and symbolic information.

But one can say that Active Sensing is an application of information theory with sensors, encoding, decision making, and control. This approach has been eloquently stated by Tenenbaum [1]: "Because of the inherent limitation of a single image, the acquisition of information through active sensing is a more effective way to perceive the world... Accommodation reduces the fundamental limitation of image inadequacy rather than the secondary problems caused by it." Although he uses the term "accommodation" rather than active sensing the message is the same.

The implications of the active sensing approach are the following:

- i) The necessity of models of sensors. This is to say, first, the model of the physics of sensors as well as the noise of sensors. Second, the model of the signal processing and

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0018-9219/88/080800-09\$01.00/0 © 1988 IEEE

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UC Berkeley

John Aloimonos
U. Maryland

Problem	Passive Observer	Active Observer
Shape for shading	Ill-posed problem. Needs to be regularized. Even then, unique solution is not guaranteed because of nonlinearity.	Well-posed problem. Unique solution. Linear equation used. Stability.
Shape from contour	Ill-posed problem. Has not been regularized up to now in the Tikhonov sense. Solvable under restrictive assumptions.	Well-posed problem. Unique solution for both monocular or binocular observer.
Shape from texture	Ill-posed problem. Needs some assumption about the texture.	Well-posed problem. No assumption required.
Structure from motion	Well posed but unstable. Nonlinear constraints.	Well posed and stable. Quadratic constraints, simple solution methods, stability.
Optic flow (area based)	Ill posed. Needs to be regularized. The introduced smoothness might produce erroneous results.	Well-posed problem. Unique solution. Might be unstable.

Revisiting active perception
Ruzena Bajcsy¹ · Yuanis Aloimonos² · John K. Trotton³ ● CrossMark

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Abstract Despite the recent successes in robotics, artificial intelligence and computer vision, a complete artificial agent needs to be built to actively sense the world. A number of ideas and results for how to accomplish this have already appeared in the past, their broader utility perhaps impeded by insufficient computational power or costly hardware. The history of these ideas, particularly selective due to our perspectives, is presented with a critical assessment of the contributions and highlighting the seminal contributions. We argue that those contributions are as relevant today as they were decades ago and that the state of modern computational tools, as poised to find new life in the robotic perception systems of the next decade.

Keywords Sensing · Perception · Attention · Control

I Introduction
Some evening, long ago, our ancestors looked up at the night sky, just as they had done, for thousands of years. But this time, it was different. For the first time, human eyes noticed something that had never been seen before. This paper presents the history of the development of the field of active perception, with an emphasis on visual perception, and highlights the major achievements in this field.

This is one of several papers published in Autonomous Robots computing the Special Issue on Active Perception.

ACKNOWLEDGMENT All authors contributed equally to all aspects of this manuscript.

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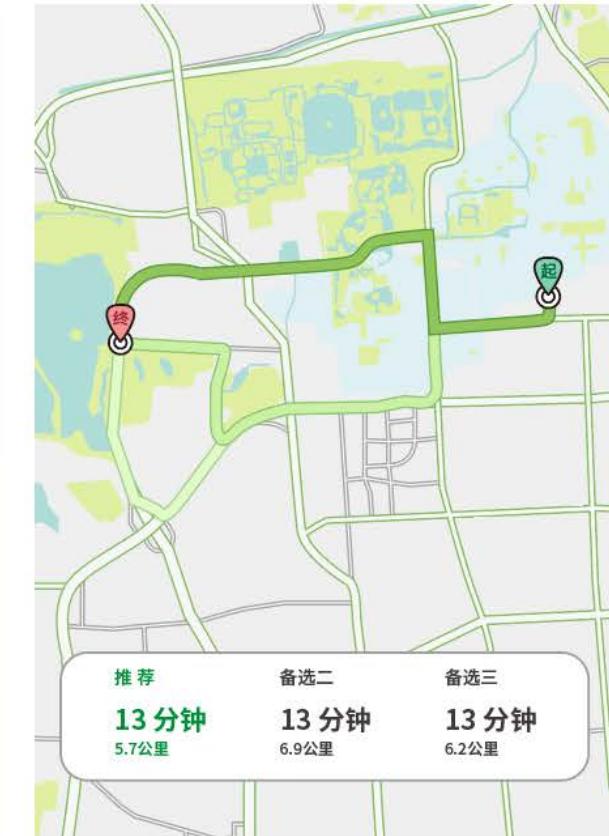
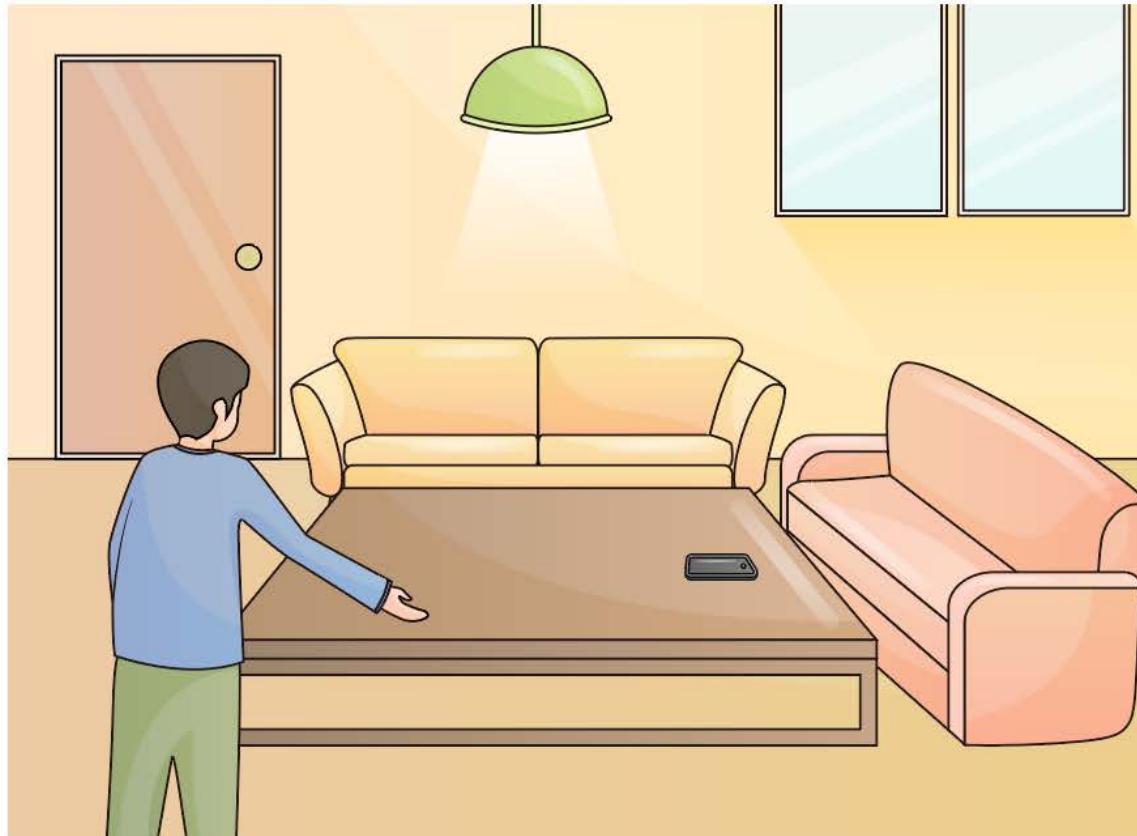
Springer

很多困难的视觉感知问题，如果允许“动一动”，其难度会显著降低。

- Aloimonos, John, Isaac Weiss, and Amit Bandyopadhyay. "Active vision." International journal of computer vision 1, no. 4 (1988): 333-356.

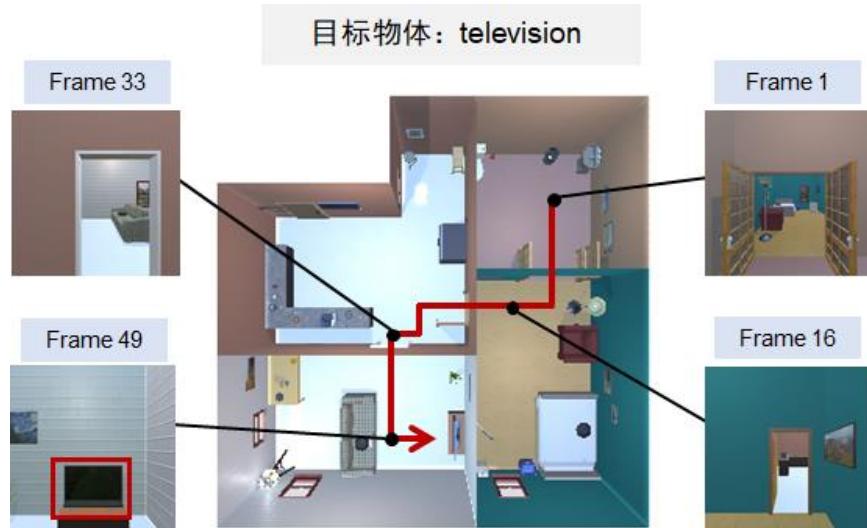
3.6 行为→感知：主动感知

➤ 视觉语义导航（Visual Semantic Navigation, VSN）



3.6 行为→感知：主动感知

➤ VSN问题描述



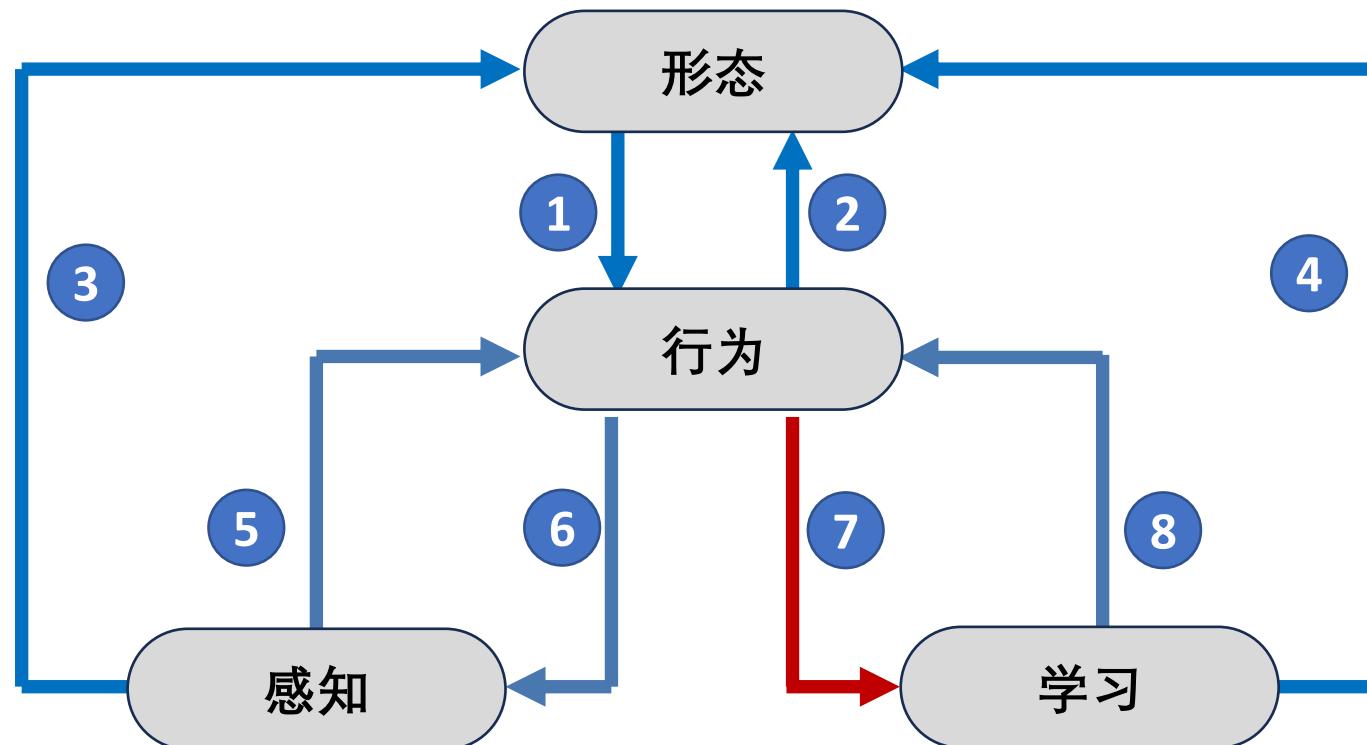
$$s_t = \varphi(I_t)$$

$$o = \phi(O)$$

$$a_t = \text{Nav}(s_t, a_{t-1}, o)$$

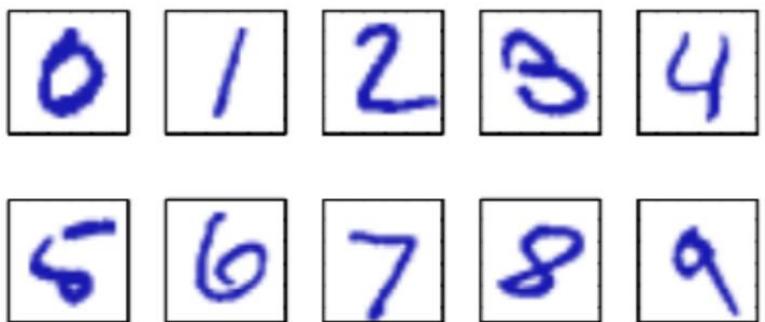
$$s_{t+1} = \text{Env}(s_t, a_t)$$

3.7 行为→学习：具身学习



3.7 行为→学习：具身学习

➤ 人是如何学习的？



3.7 行为→学习：具身学习

➤ 问题描述

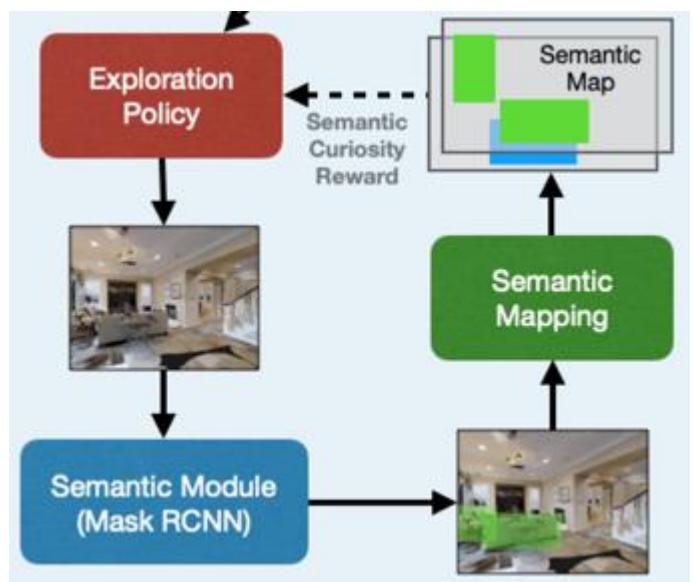


3.7 行为→学习：具身学习

➤ 问题描述

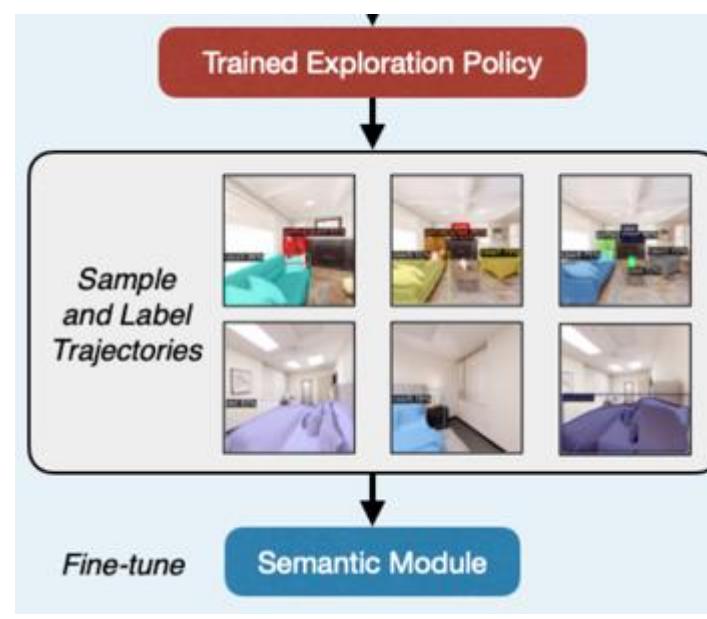
学习探索路径

学习如何探索环境才能获得更好的样本



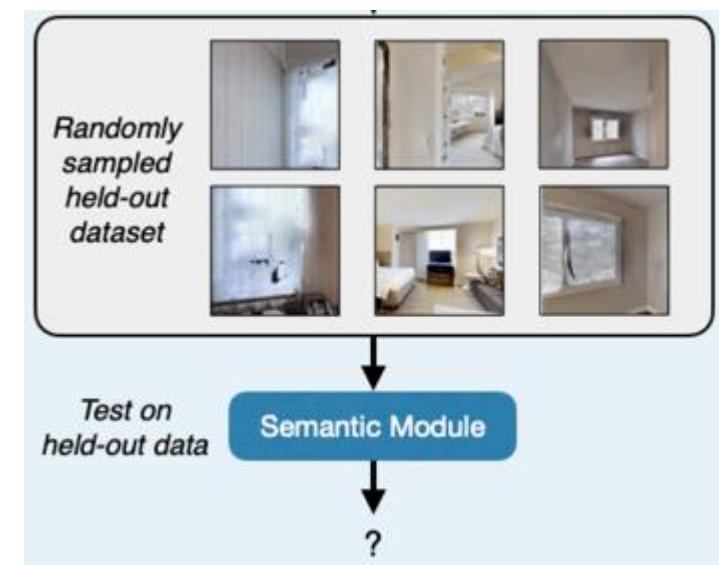
采集训练样本

利用探索策略获取样本与标签，提升感知器性能



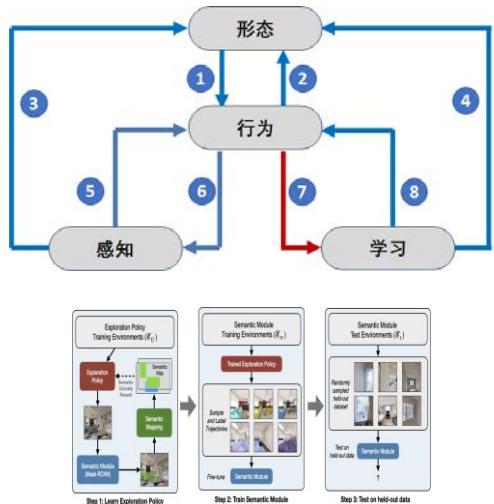
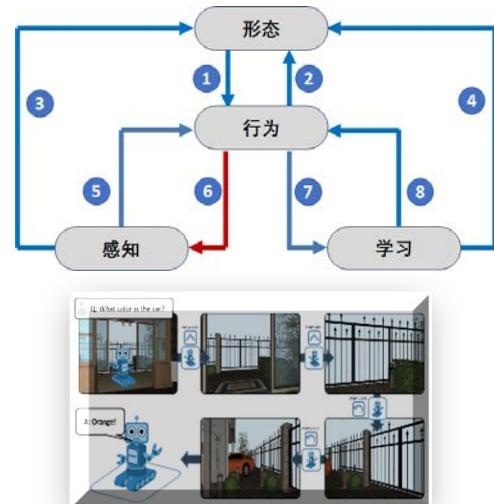
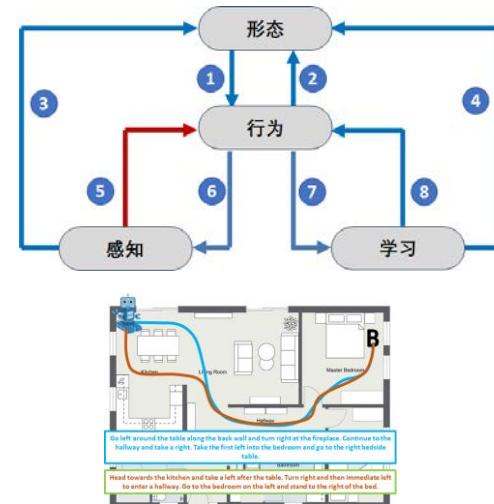
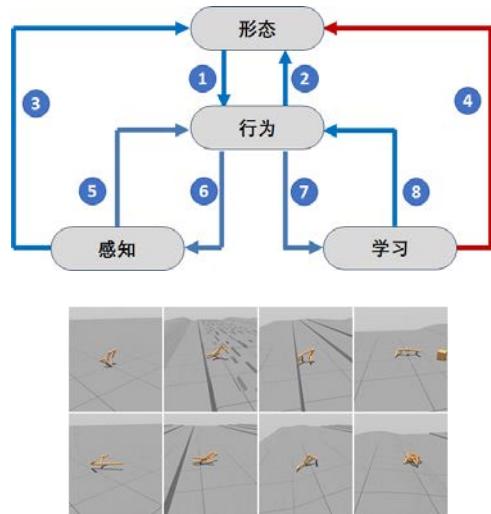
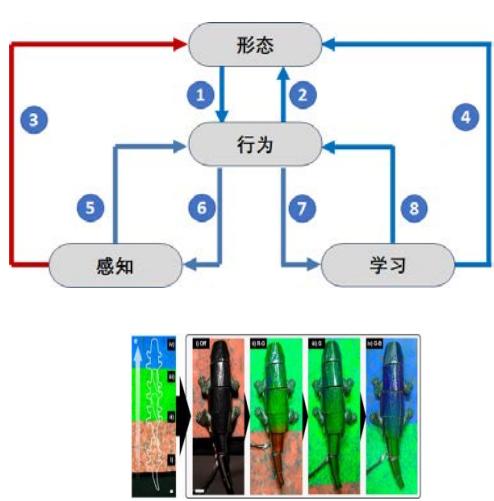
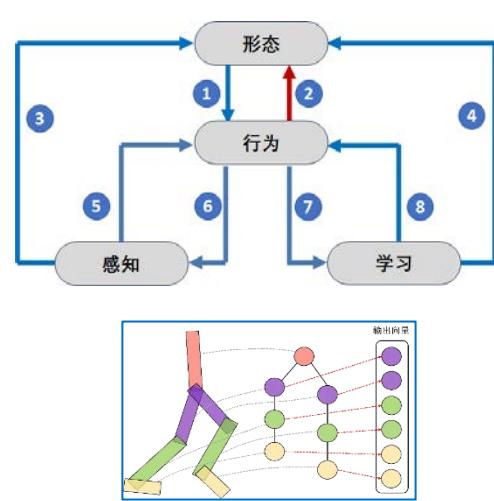
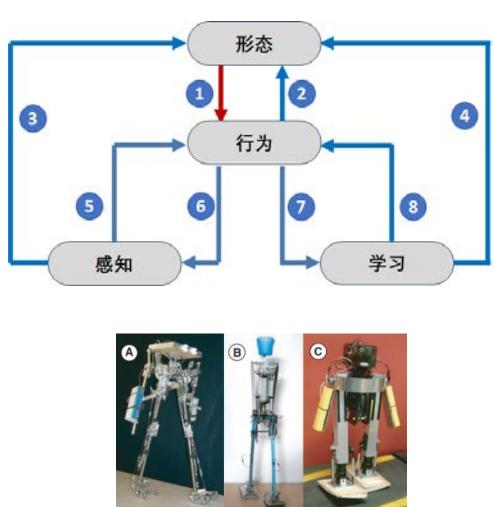
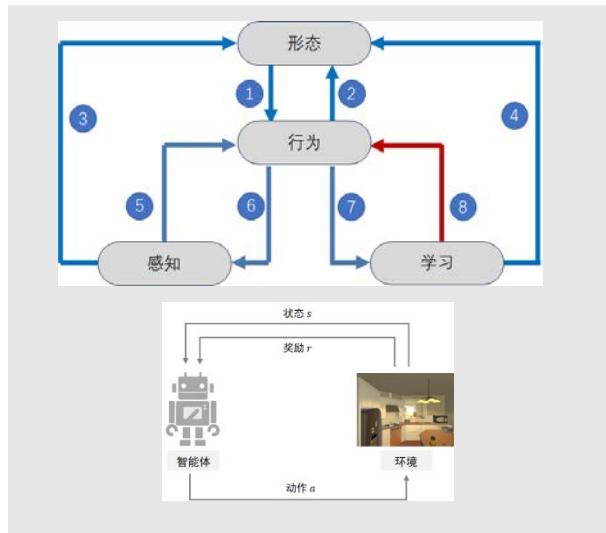
部署应用

在新场景中对改进的感知器进行测试



3.8 总结

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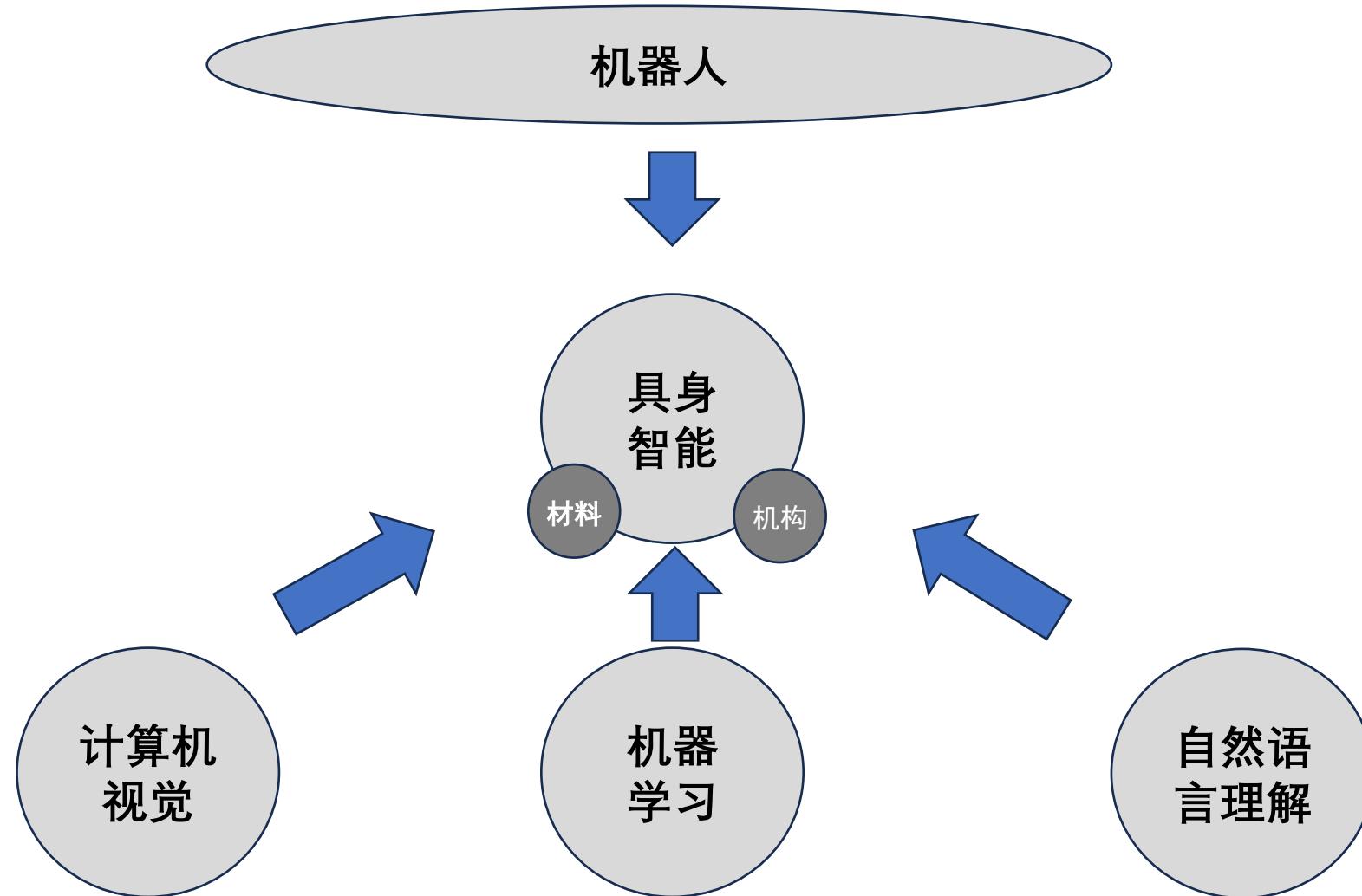


-
- 1 具身智能的背景
 - 2 具身智能的体系
 - 3 具身智能的关键技术
 - 4 具身智能的前沿发展

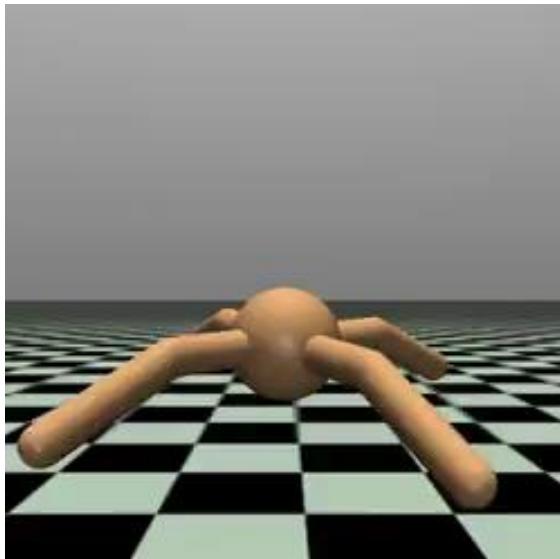
总 结

总结

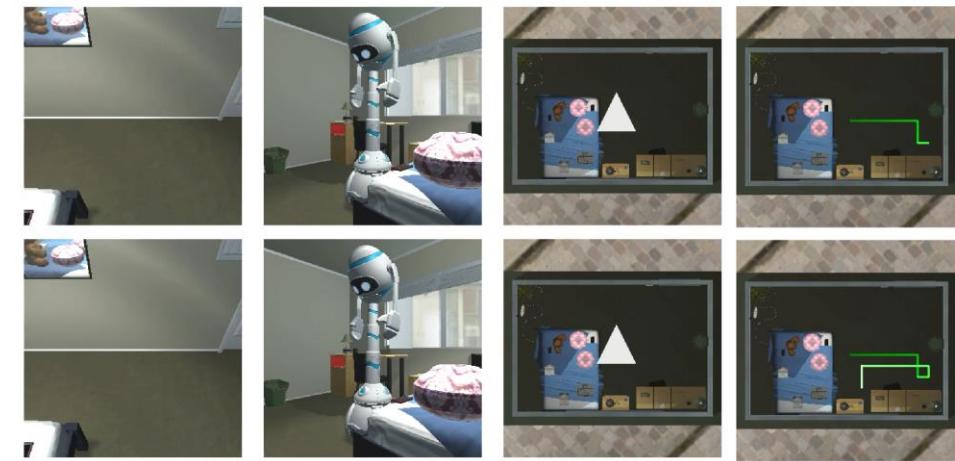
➤ 多学科交叉



- 以感知、学习技术为手段，研究如何为机器人赋予智能
- 探讨机器人智能的实现
- 探讨具身智能的内涵与外延



Success Sample of Remove Object Attack in GotoLocation Task



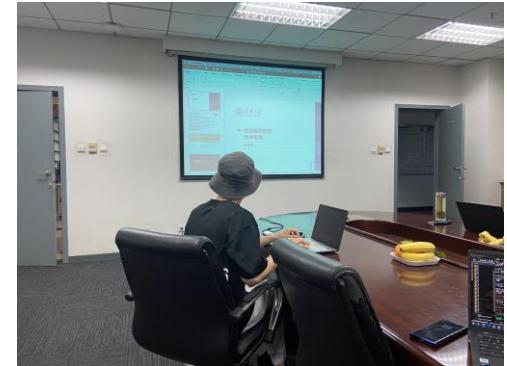
Remove **TissueBox** from Desk **Instr:** Turn around , move to the clock on the small table left of the bed.

课程内容安排

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周	上课内容	软件
1	绪论	
2	深度学习	TensorFlow, pyTorch
3	强化学习1	Gym, V-Rep
4	强化学习2	Gym, V-Rep
5	自监督、持续与主动学习	TensorFlow, pyTorch
6	作业准备	
7	开题	Powerpoint
8	形态智能	Gym, V-Rep
9	视觉语言导航: VLN	AI2THOR
10	主动语义感知: VSN, EQA	
11	具身学习	AI2THOR
12	五一放假	AI2THOR
13	多体智能	AI2THOR
14	具身大模型	AI2THOR
15-16	成果准备与展示	Powerpoint

- 第7周前，完成组队（1-3人）
- 第7周，集中完成选题报告审核（2页word）。10分钟左右ppt
- 第8-14周，将有针对性地围绕有代表性的选题展开专题研讨（助教参与）
- 第15-16周，集中展示成果（书面报告、10分钟ppt，展示Demo）
- 分数：根据最终展示成果综合打分
- 对有兴趣开展后续工作的同学，协助指导修改报告，提供实验等条件。鼓励投稿。



1人组队

- 完成基础任务要求，提交代码，并正常运行
- Demo可展示
- Demo展示覆盖不少于1种情形

$\leq A-$

$> A-$

2人组队

- 完成基础任务要求，提交代码，并正常运行
- 提交完整的设计文档（论文草稿）
- Demo展示度高
- Demo展示不少于2种情形
- 有明确的后续改进思路
- 明确人员分工

$\leq A-$

$> A-$

3人组队

- 超出基础任务要求，提交代码，并正常运行
- 算法有特色
- 提交完整的设计文档（论文草稿）
- Demo展示度高
- Demo展示不少于2种情形
- 有明确细化的后续改进方案
- 明确人员分工

$\leq A-$

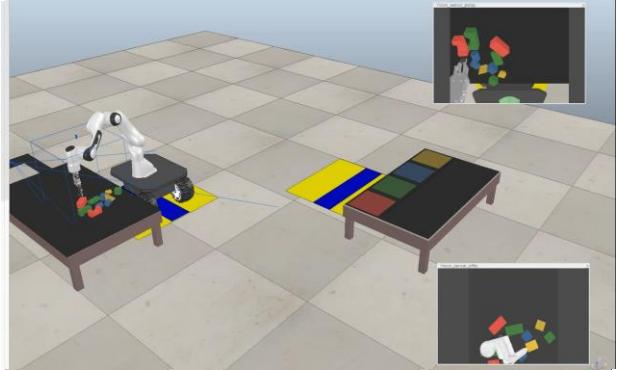
- Demo可交互
- 展示效果靓
- 算法有创新

$> A-$

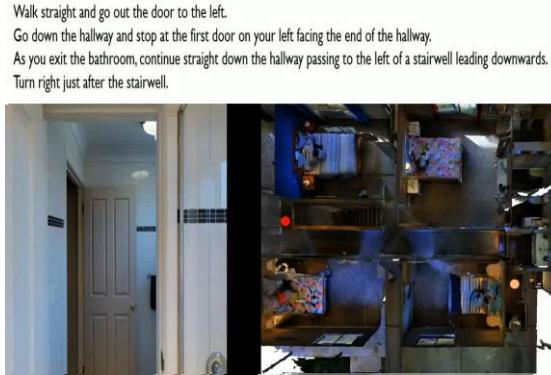
考核方式

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作业展示



陈同学，武同学



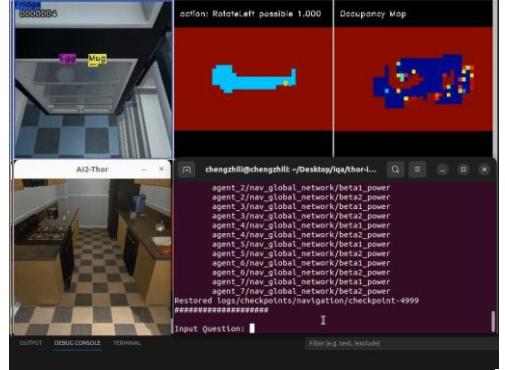
王同学

ChatGPT ?

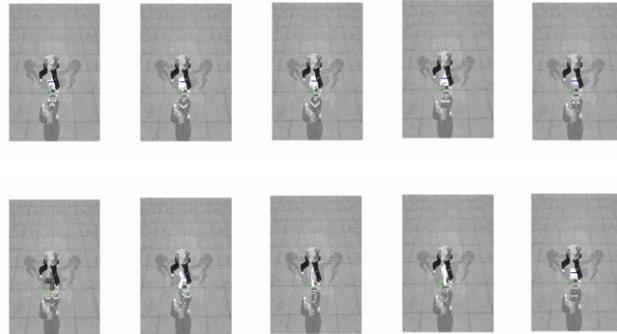
Prompt

```
[{"role": "system", "content": "You are an agent ... you see ... You task is to: heat some potato and put it in sinkbasin. ..."}, {"role": "assistant", "content": "Action: look"}, {"role": "user", "content": "Observation: You are in the middle of a room. Looking quickly around you, you see nothing.\nAvailable actions: go to cabinet 1; go to toaster 1; inventory; look"}]
```

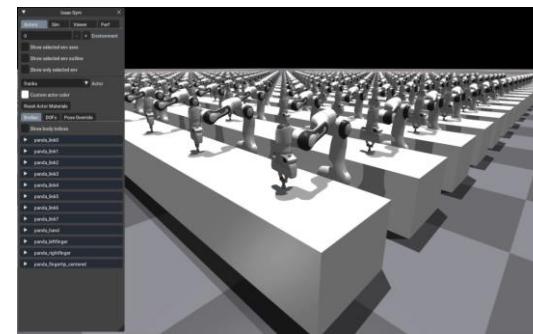
=> Welcome to TextWorld!, ALFRID! =
You are in the middle of a room. Looking quickly around you, you see a cabinet 8, sink 1, a stoveburner 4, a stoveburner 3, a stoveburner 2, a stoveburner 5, and a stoveburner 6.
Your task is to: heat some potato and put it in sinkbasin.
> go to fridge 1
> take potato from fridge 1
Invalid action!
> examine fridge 1
> go to sinkbasin 1
> take potato from fridge 1
Invalid action!
> go to cabinet 1
You arrive at loc 4. On the cabinet 1, you see a bowl 1.
> take bowl 1 from cabinet 1
> go to sinkbasin 1
You open the microwave 1. The microwave 1 is closed.
> open microwave 1
You open the microwave 1. The microwave 1 is open. In it, you see nothing.
> put bowl 1 in/on the microwave 1
You put the bowl 1 in/on the microwave 1.
> close microwave 1
You close the microwave 1.
> set microwave 1 for 3 minutes
Invalid action!
> go to sinkbasin 1
You open the microwave 1. The microwave 1 is open. In it, you see a bowl 1.
> take bowl 1 from microwave 1
You pick up the bowl 1 from the microwave 1.
> go to sinkbasin 1
You arrive at loc 2. The fridge 1 is open. In it, you see a cup 3, a lettuce 1, and a mug 3.



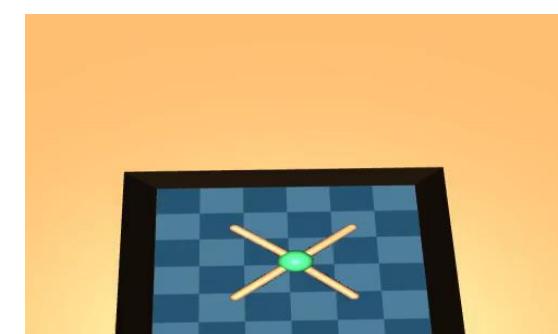
郑同学



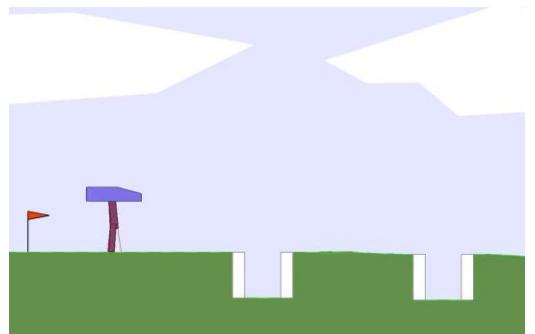
燕同学



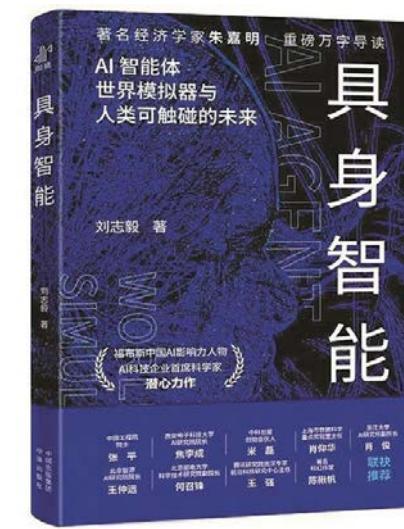
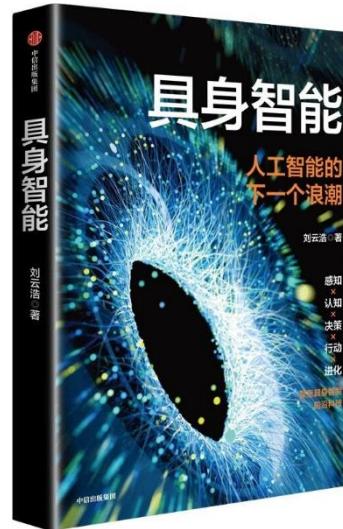
郭同学



范同学，张同学



黄同学，陈同学



- 什么叫具身智能？
- 如何实现具身智能？
- 如何研究具身智能？
- 具身智能与机器人智能的关系？
- 具身智能与大模型的关系？
- 具身智能与AIGC的关系？

最有钱的具身智能实验室？

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Google

Boston Dynamics

Meta

Microsoft



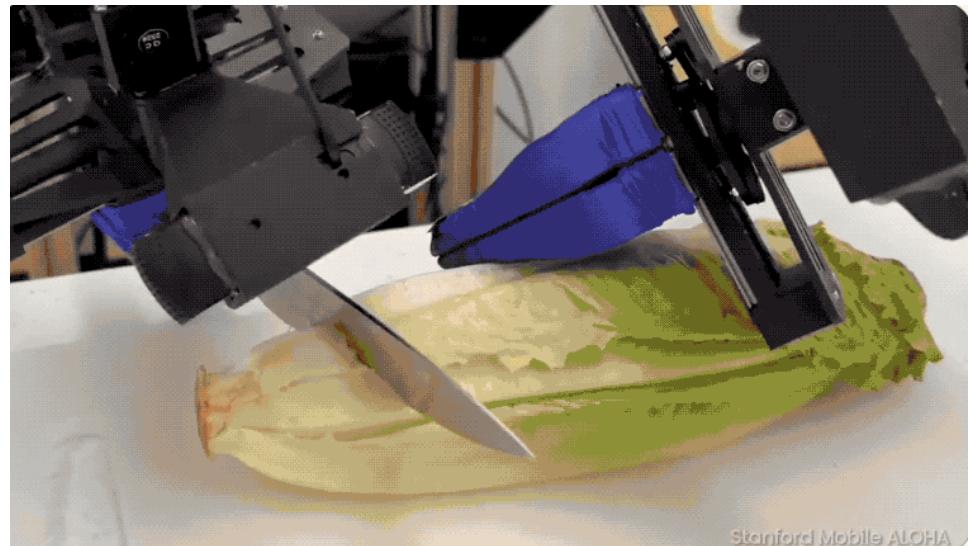
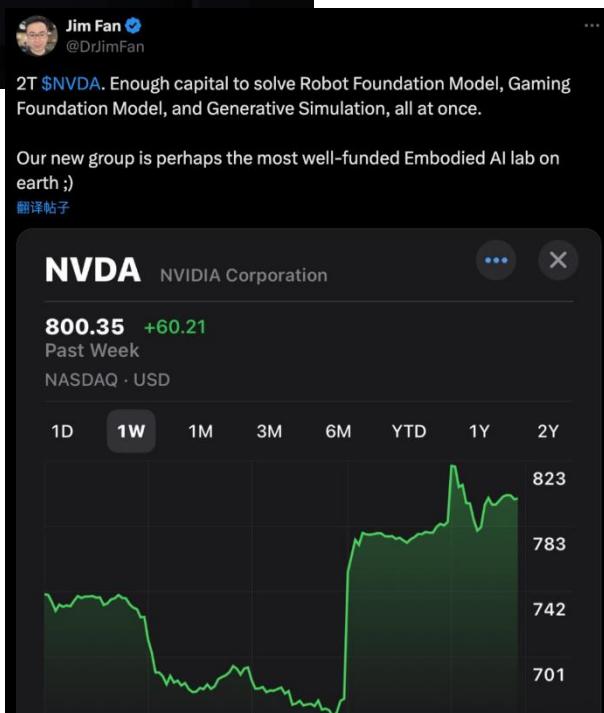
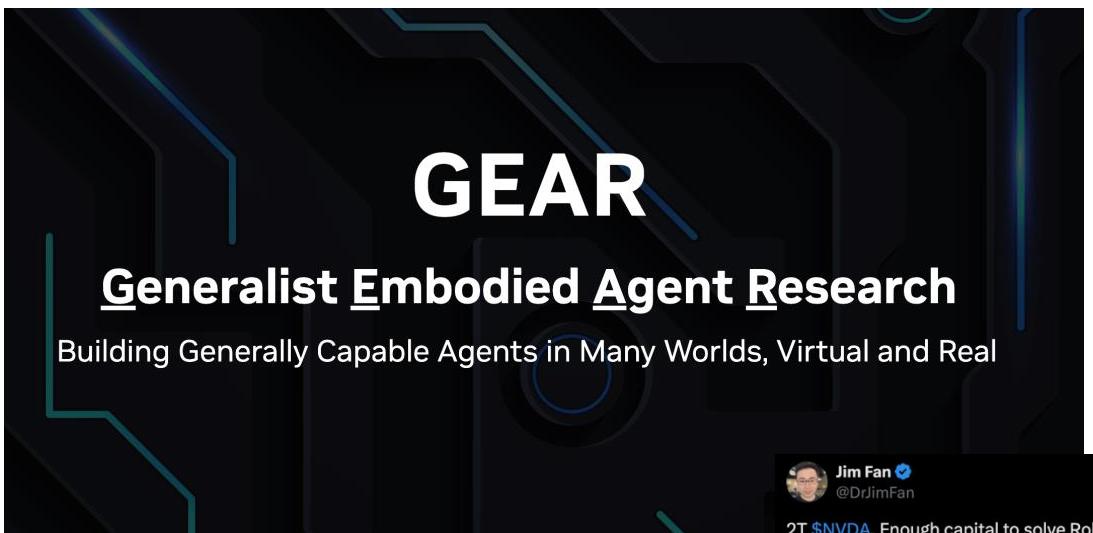
NVIDIA®



OpenAI

最有钱的具身智能实验室？

80



浅晓终来得上纸
行躬要事此知绝

谢 谢 !