全国高校自动化专业系列课程研修班（第15期）

智能科学研究进展

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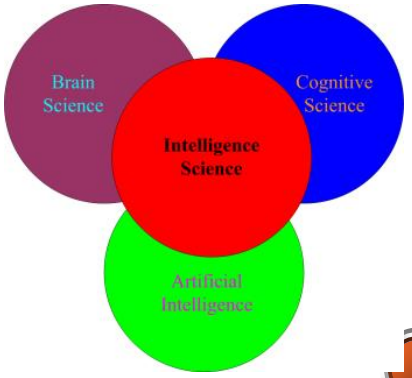
中科院计算所

INSTITUTE OF COMPUTING TECHNOLOGY

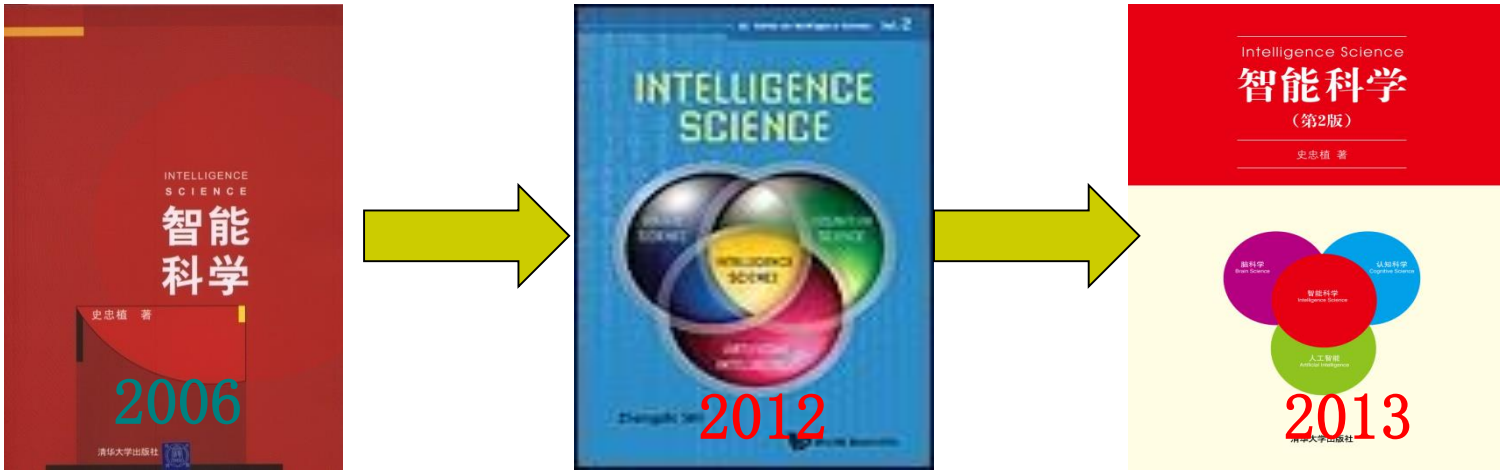
内容提要



- 概述
- 心智模型
- 机器意识系统
- 脑机融合
- 结束语

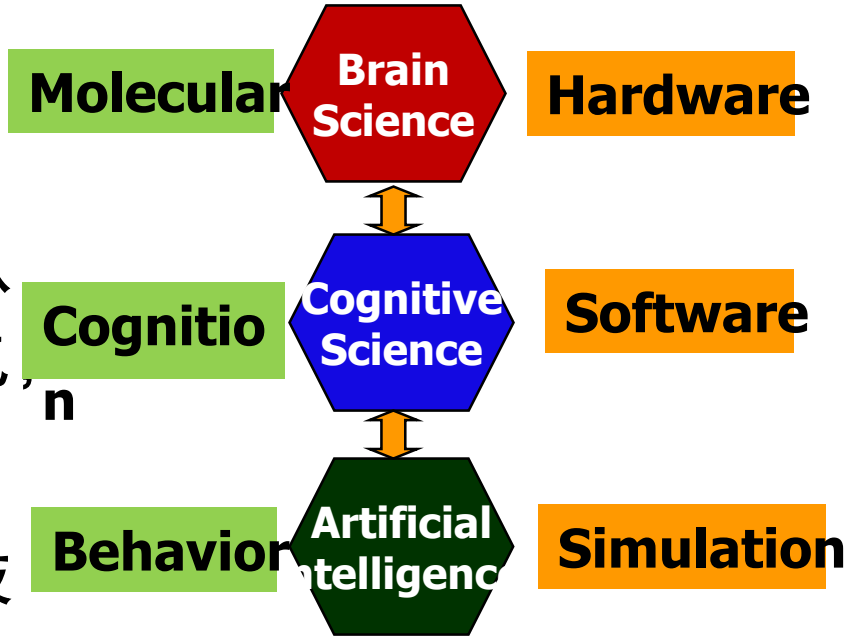
智能科学

智能科学主要由脑科学、认知科学、 人工智能等组成的交叉学科，研究智能的理论和技术。智能科学不仅要进行智能的功能仿真，而且要研究智能的机理， 探索智能的新理论、新方法、新技术。



智能科学

- 脑科学探索大脑的本质，在分子和细胞水平研究自然智能的原理，建立脑模型。
- 认知科学在行为水平研究人的认知心理活动，如知觉，学习，记忆，思维，意识等。
- 人工智能试图用人工的方法和技术模拟、延伸和扩展人类的智能，



基本科学问题（1）

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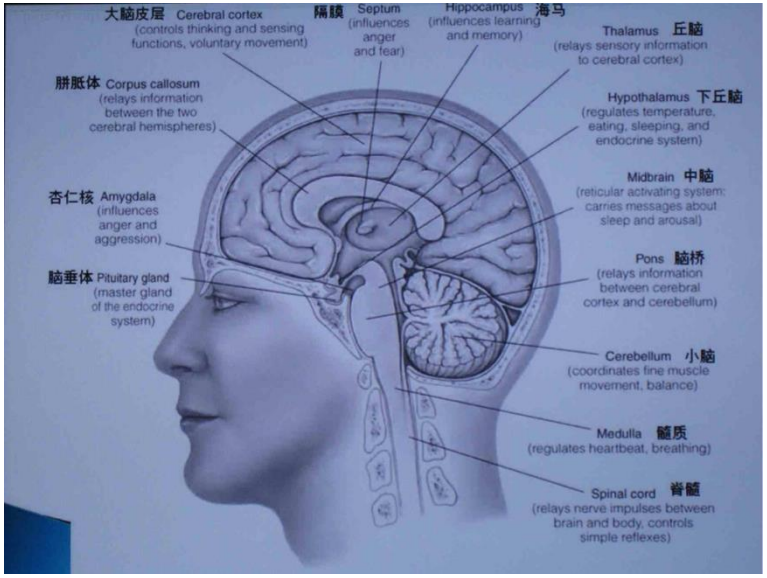
神经活动的基本过程

☞神经信号的发生、转导、传导、突触传递等。

☞神经递质的合成、维持、释放及与受体的相互作用的研究都取得了令人瞩目的进展。

☞对神经元和神经系统发育的分子机制的研究



基本科学问题（2）

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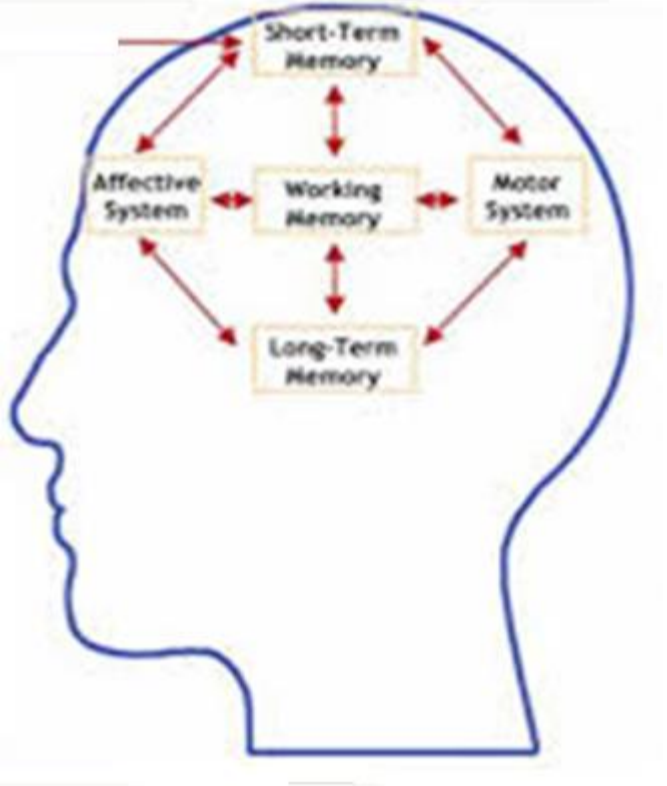
脑的感知过程和知觉表达

知觉信息的表达是知觉研究的基本问题，是研究其它各个层次认知过程的基础。知觉过程是从那里开始的？外在物理世界的那些变量具有心理学的知觉意义？作为知觉的计算模型计算的对象是什么？

基本科学问题（3）

记忆过程中的信息处理

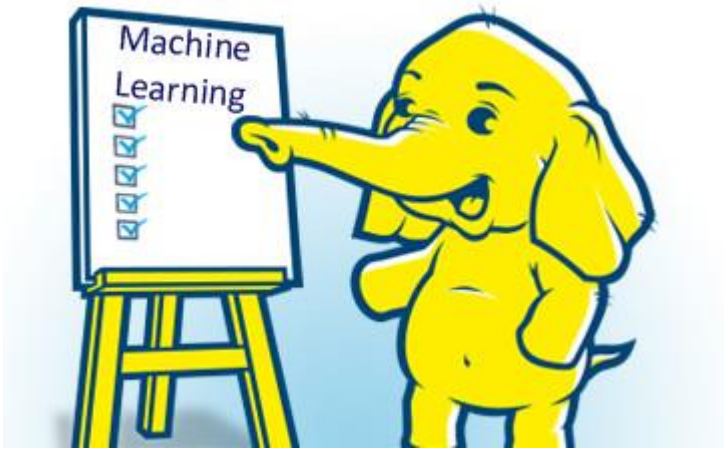
记忆在智能活动中占有突出的位置，记忆能力也是智能水平的重要标志之一。在内容上，记忆可分为陈述性记忆（包括情景记忆和语义记忆等）和非陈述性记忆（包括启动效应、运动技巧、习惯等）；在时间上，记忆又可分为感知记忆、短时记忆和长时记忆。工作记忆是一种短时记忆，它的功能是短时间“在线”式地保存和处理信息，是多种高级认知功能的核心环节。



基本科学问题（4）

学习过程中的信息处理，感性认识与理性认识的相互关系

学习在脑内如何发生，是神经生物学的核心问题之一。学习导致神经系统结构和功能上的精细修饰，形成记忆痕迹。揭示学习的神经机制，对理解人类智力的本质具有重大意义。



基本科学问题（5）

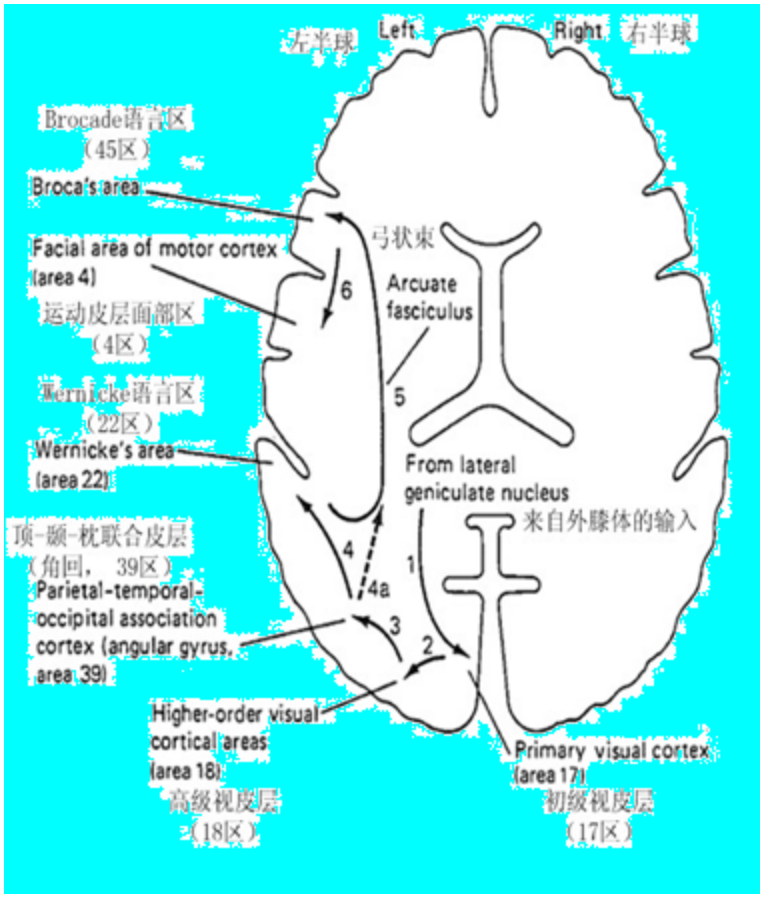
语言加工的认知机制

☞语言的中枢表象是什么？语言加工的认知和脑机制

理解和使用语言是人类特有的功能，是人类意识和意志表达的基本途径。

☞汉语以其独特的词法和句法体系、文字系统和语音声调系统而显著区别于印欧语言。

☞从神经、认知、和计算三个层次上研究汉语加工和信息处理是摆在我国科学家面前刻不容缓的任务。



基本科学问题（6）

思维的认知机理

思维是具有意识的人脑对于客观现实的本质属性、内部规律性的自觉的、间接的和概括的反映。

☞通过研究不同层次的思维模型，研究思维的规律和方法，为新型智能信息处理系统提供原理和模型。

☞ 近年来神经生理学和脑科学的研究成果表明，脑的感知部分，包括视觉、听觉、运动等脑皮层区不仅具有输入/输出通道的功能，而且具有直接参与思维的功能，。智能不仅是运用知识，通过推理解决问题，智能也处于感知通道

基本科学问题（7）

智力发育

个体自出生后在适应环境的活动中，对事物的认识以及面对问题情境时的思维方式与能力表现，随年龄增长而逐渐改变的历程。

基本科学问题（8）

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情感系统

情感（emotion）是人们对客观事物的主观态度和相应的内心体验。

情感活动与大脑边缘系统和植物神经系统有着重要的联系。大脑皮层则调节着情绪和情感的进行，控制着皮层下中枢的活动。包括丘脑、下丘脑、边缘系统和网状结构的机能。动物实验表明边缘系统的5-羟色胺和去甲肾上腺素含量最高。并对情感活动的调节起重要作用。

基本科学问题（9）

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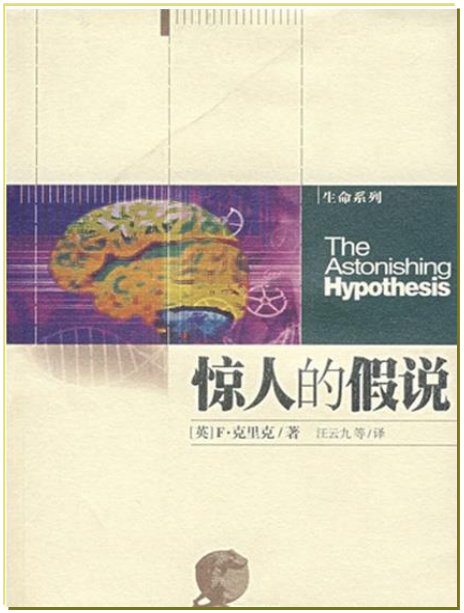
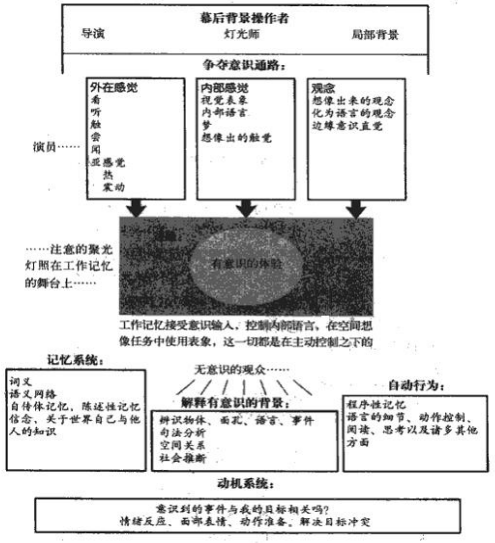
意识问题

意识是人脑对外部世界和自身心理、生理活动等客观事物的觉知和控制。意识问题是对当代科学的巨大挑战。





基本科学问题（10）

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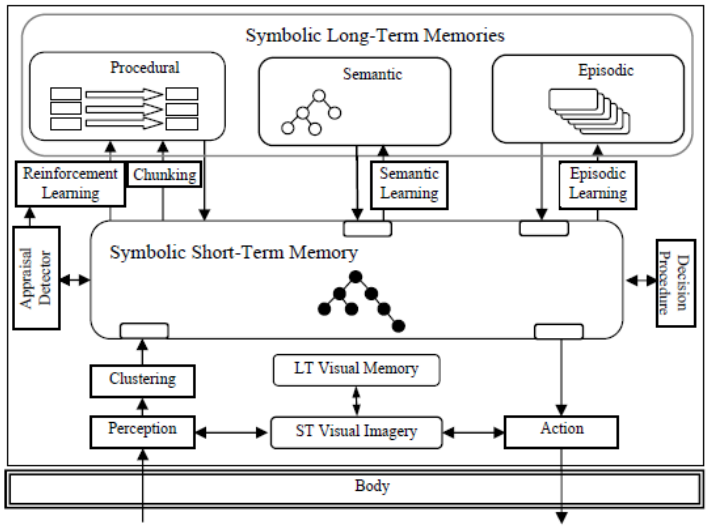
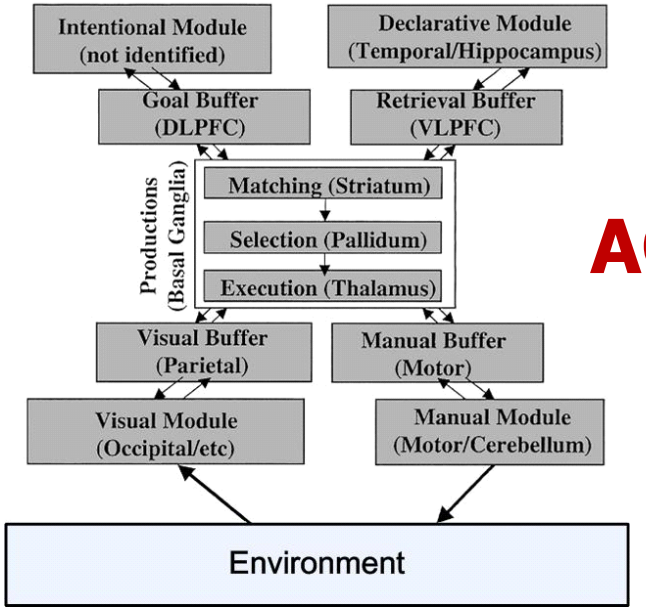
心智模型

心智建模是使用信息理论和技术对人类全部精神活动进行建模，包括意识、思维、推理、记忆、学习、情感、感知等。

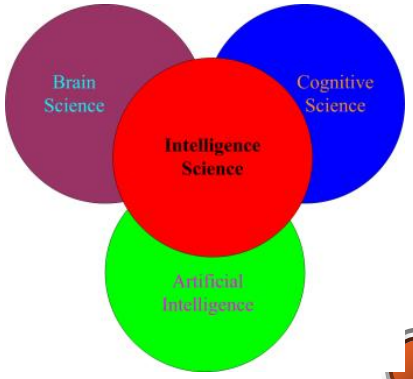


SOAR



ACT-R

内容提要



- 概述
- 心智模型
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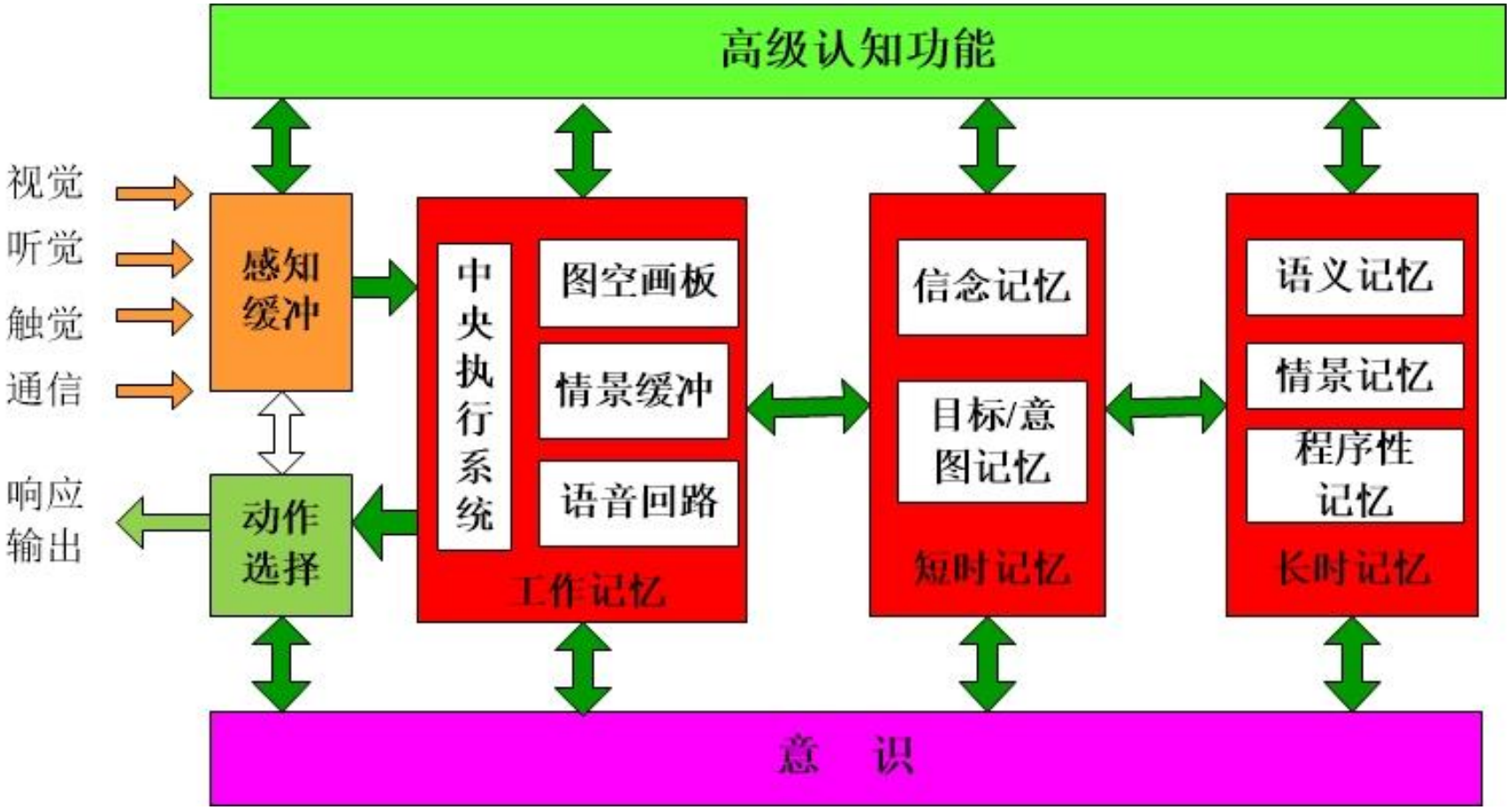
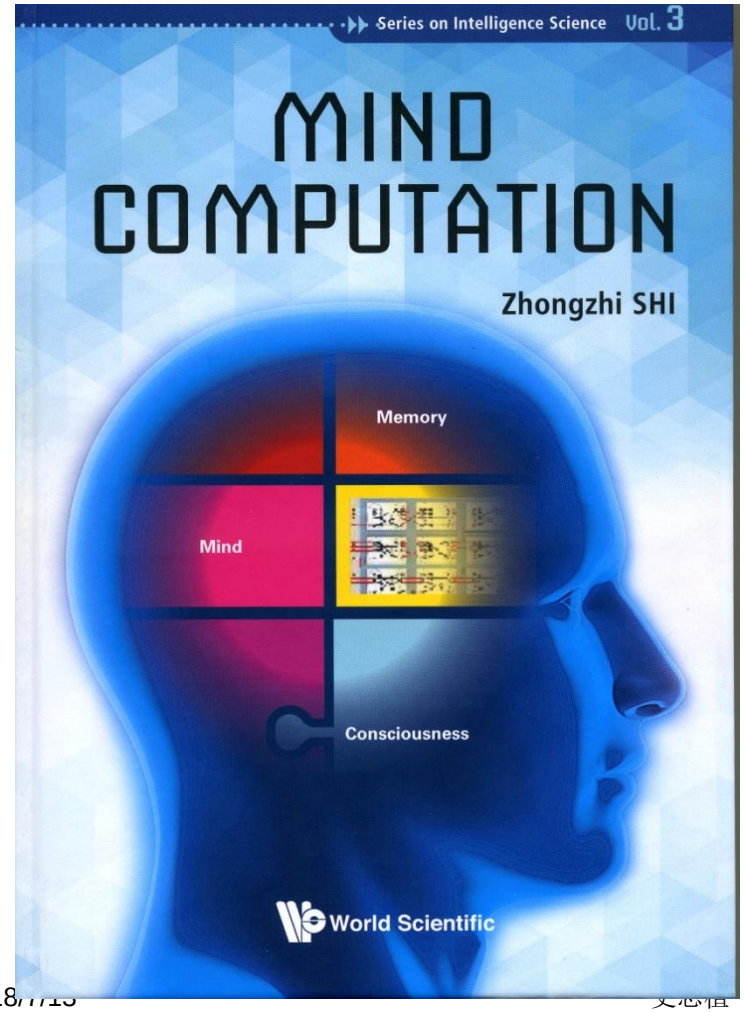
心 智

心智(mind)是脑的精神活动的总称，包括感觉、知觉、学习、记忆、注意、情感、意志、兴趣、性格、思维等大脑活动的一切方面。神经系统看成是脑的硬件，心智可以看成脑的软件。

心智模型 CAM


高级认知功能
视觉
听觉
触觉
通信
响应输出
感知缓冲
动作选择
中央执行系统
图空画板
情景缓冲
语音回路
工作记忆
信念记忆
目标/意图记忆
短时记忆
语义记忆
情景记忆
程序性记忆
长时记忆
意 识

心智计算Mind Computation

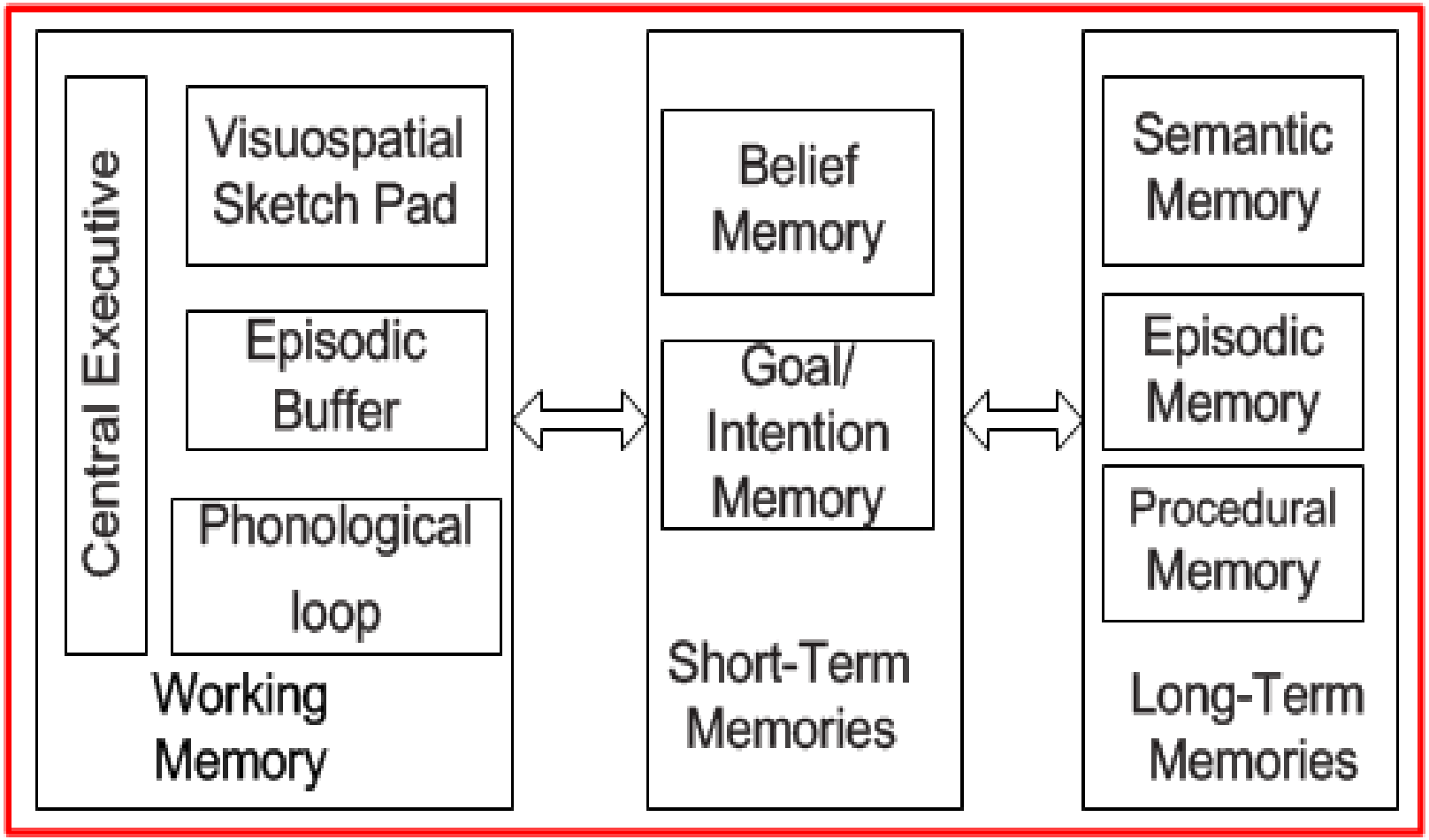


1. Introduction
2. Mind Model CAM
3. Memory
4. Consciousness
5. Visual Awareness
6. Motor Control
7. Linguistic Cognition
8. Learning
9. Brain-like Computing

记 忆

- **Working memory**: It includes the central executive, visuospatial sketch pad, phonological loop and episodic buffer.
- **Short-term memory**: Stores agent's beliefs, goals and intention contents
- **Long-term memory**: Contains semantic, episodic and procedural knowledge.

记 忆


Central Executive
Visuospatial Sketch Pad
Episodic Buffer
Phonological loop
Working Memory
Belief Memory
Goal/ Intention Memory
Short-Term Memories
Semantic Memory
Episodic Memory
Procedural Memory
Long-Term Memories

大脑皮质分区

- 按进化

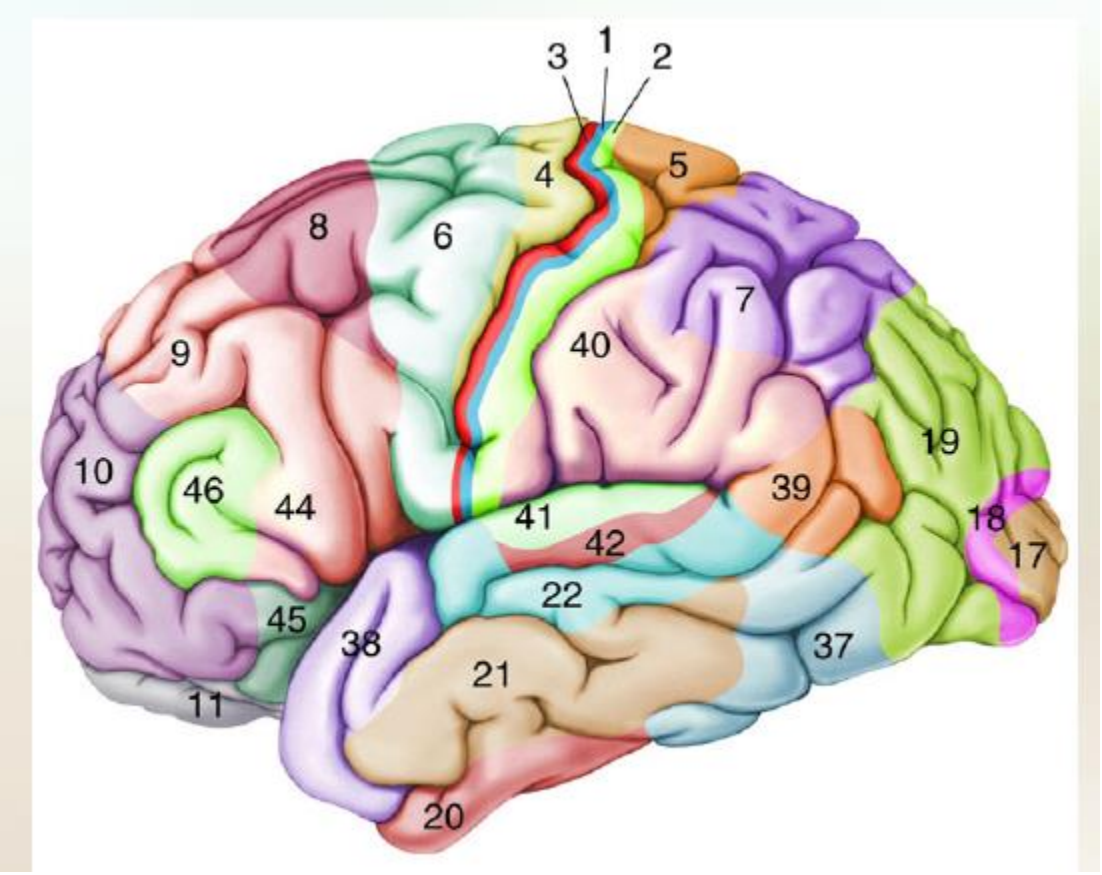
原皮质：海马、
齿状回

旧皮质：嗅脑、

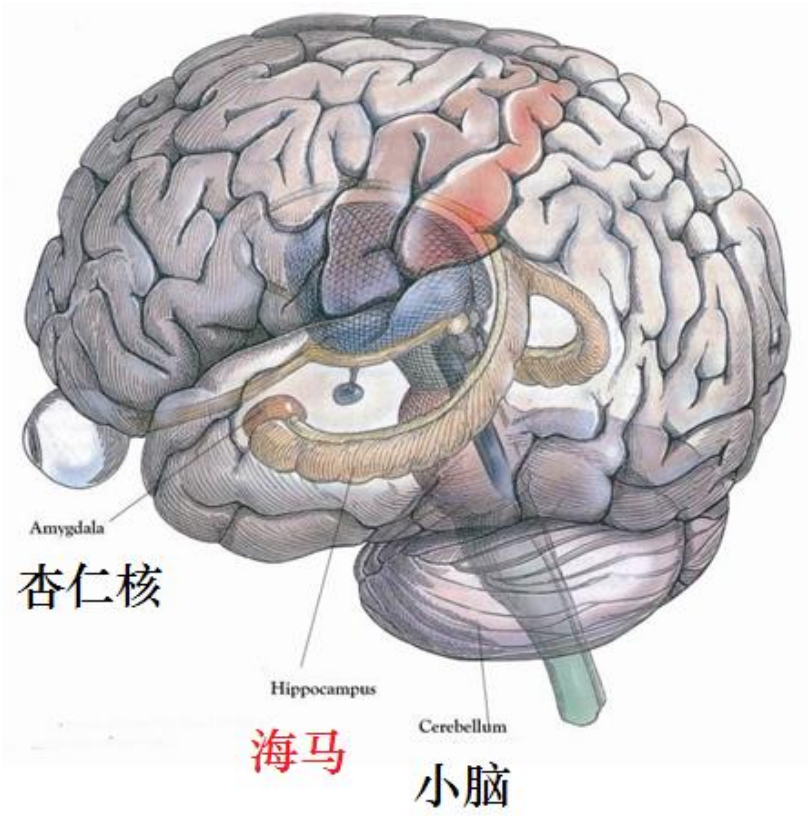
新皮质：绝大部分

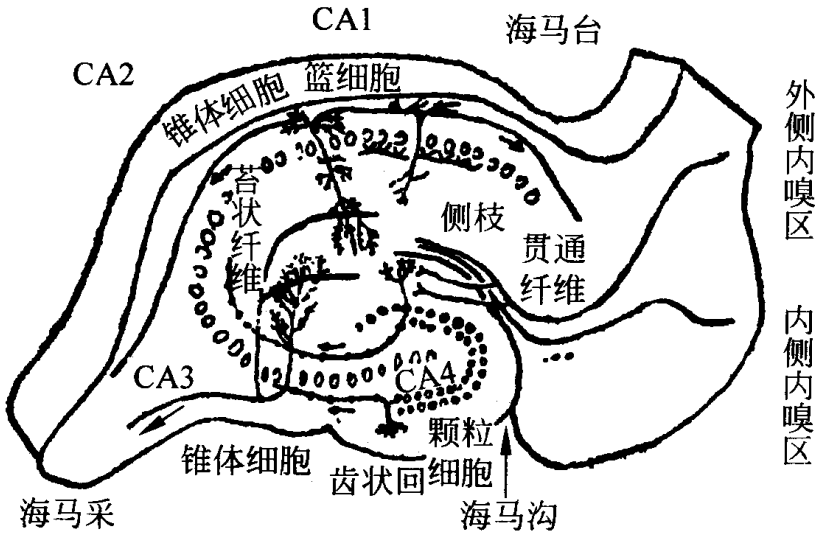
- Brodmann分区：

按细胞构筑和
神经纤维的分布
分52个不同脑区



海马体的构造


Amygdala
杏仁核
Hippocampus
海马
Cerebellum
小脑


CA1
海马台
CA2
锥体细胞
篮细胞
苔状纤维
侧枝
贯通纤维
外侧内嗅区
内侧内嗅区
CA3
CA4
颗粒细胞
锥体细胞
齿状回
海马采
海马沟

海马体的构造

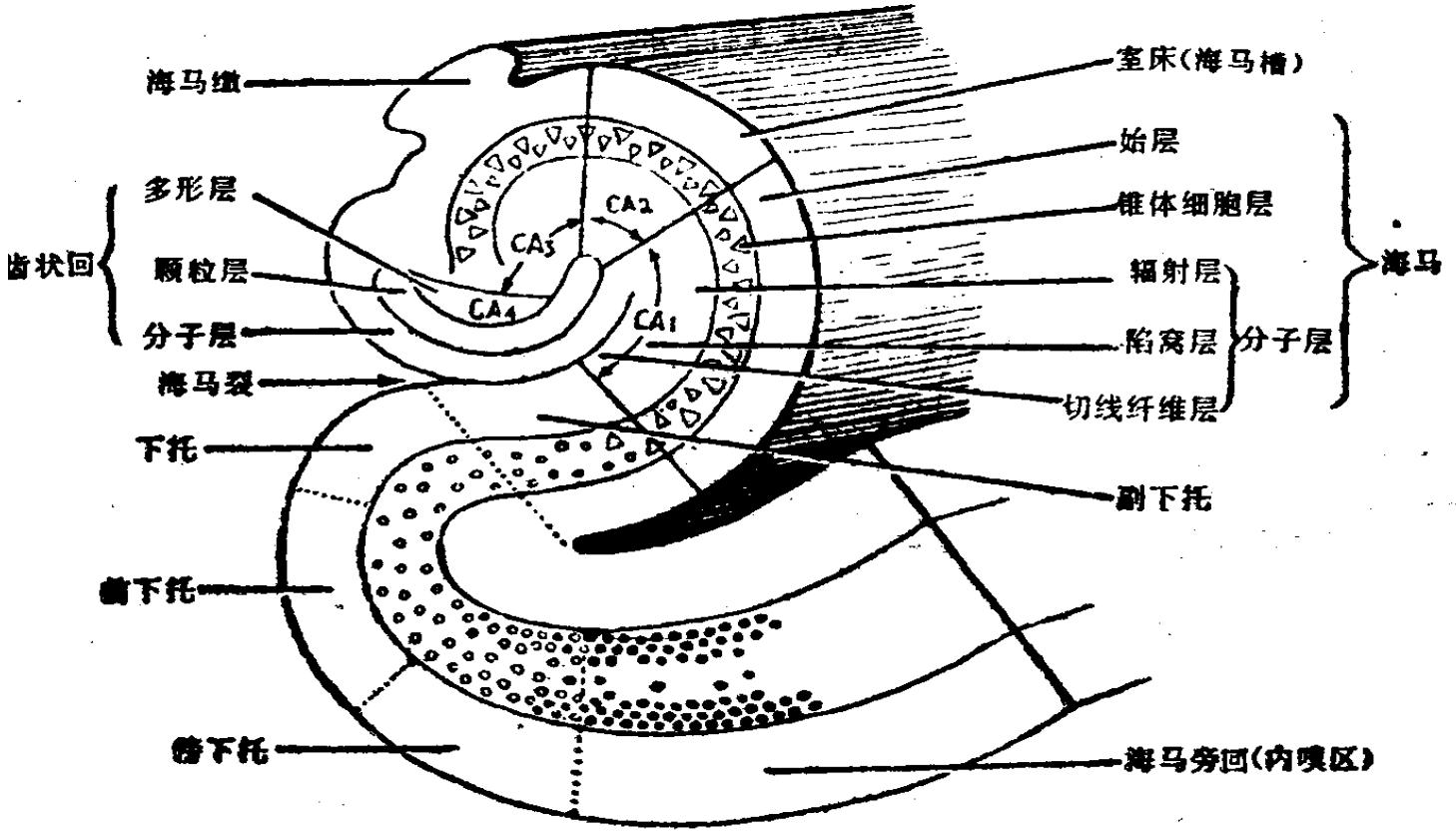
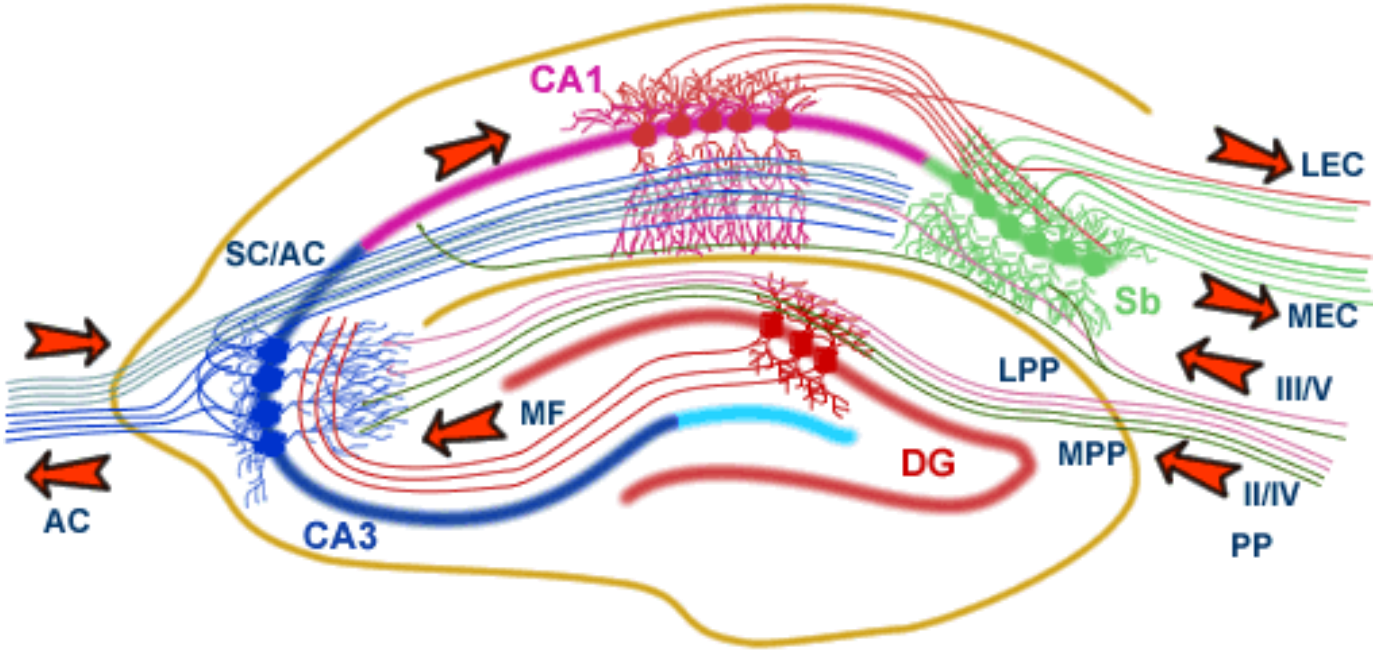


图 7—18　海马的皮质分层与分区

海马回路



The Hippocampal Network: The hippocampus forms a principally uni-directional network, with input from the Entorhinal Cortex (EC) that forms connections with the Dentate Gyrus (DG) and CA3 pyramidal neurons via the Perforant Path (PP - split into lateral and medial). CA3 neurons also receive input from the DG via the mossy fibres (MF). They send axons to CA1 pyramidal cells via the Schaffer Collateral Pathway (SC), as well as to CA1 cells in the contralateral hippocampus via the Associational Commissural pathway (AC). CA1 neurons also receive input directly from the Perforant Path and send axons to the Subiculum (Sb). These neuron in turn send the main hippocampal output back to the EC, forming a loop.

互补学习系统

James L. McClelland于1995年提出了互补学习系统（complementary learning systems，CLS）理论。该理论认为人脑学习是两个互补学习系统的综合产物。一个是大脑新皮质学习系统，通过接受体验，慢慢地对知识与技能进行学习。另一个是海马体学习系统，记忆特定的体验，并让这些体验能够进行重放，从而与新皮质学习系统有效集成。

- *J. L. McClelland, et al., "Why there are complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory", Psychol. Rev. 102, 419–457, 1995.*

2013年访问McClelland教授

互补学习系统

2016年，谷歌深度思维的库玛拉（Dharshan Kumaran）、哈萨比斯（Demis Hassabis）和斯坦福大学的麦克莱伦德在《认知科学趋势》刊物上发表文章，拓展互补学习系统理论。大脑新皮质学习系统是结构化知识表示，而海马体学习系统则迅速地对个体体验的细节进行学习。

- *D. Kumaran, D. Hassabis, J. L. McClelland, "What Learning Systems do Intelligent Agents Need? Complementary Learning Systems Theory Updated", Trends in Cognitive Sciences, Vol. 20, No. 7: 512-534, 2016.*

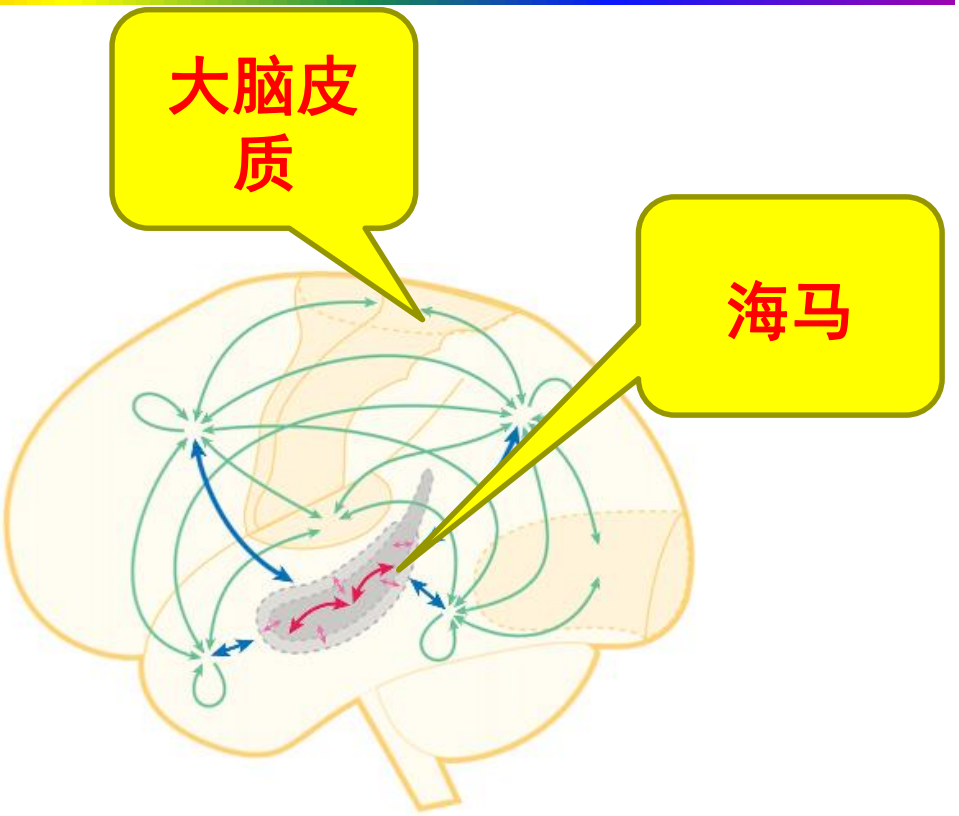
互补学习系统

哈萨比斯等对海马体记忆重放的作用进行了拓展，指出记忆重放能够对体验统计资料进行目标依赖衡量。通过周期性展示海马体踪迹，支持部分泛化形式，新皮质对于符合已知结构知识的学习速度非常迅速。互补学习系统理论与人工智能的智能体设计之间的相关性，突出了神经科学与机器学习之间的关系。

- *D. Kumaran, D. Hassabis, J. L. McClelland, "What Learning Systems do Intelligent Agents Need? Complementary Learning Systems Theory Updated", Trends in Cognitive Sciences, Vol. 20, No. 7: 512-534, 2016.*

互补学习系统

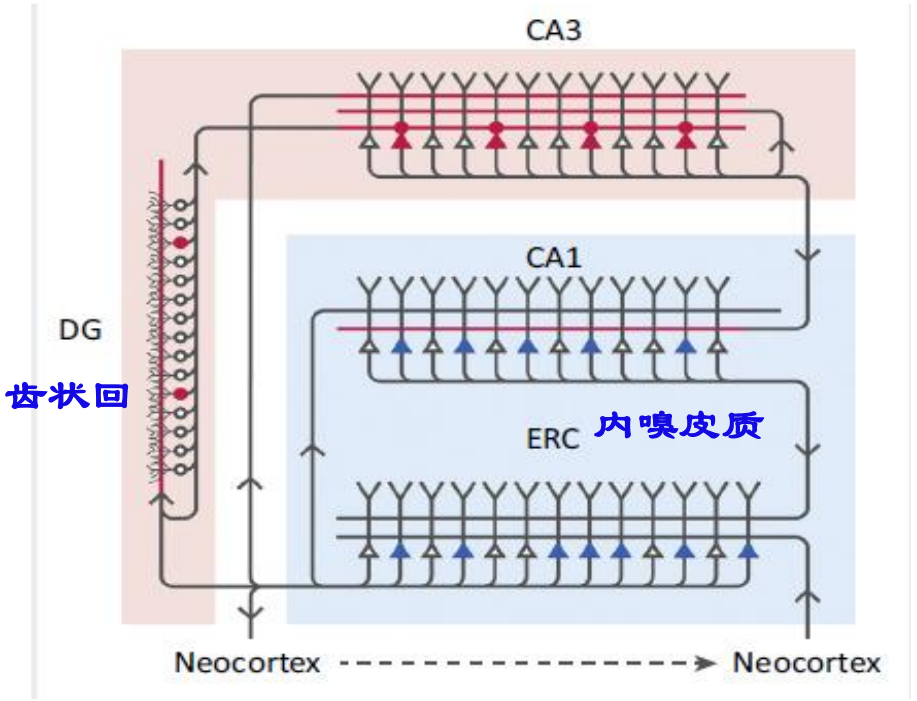
感觉和运动皮质显示为深黄色。内侧颞叶（medial temporal lobe，MTL）包围虚线，海马以深灰色和周围的内侧颞叶（MTL）皮质浅灰色（大小和位置是近似的）。绿色箭头表示整合的新皮层关联区域内和之间，以及在这些区域和模态特定区域之间的双向连接。蓝色箭头表示新皮质区域和内侧颞叶（MTL）之间的双向连接。



- *D. Kumaran, D. Hassabis, J. L. McClelland, "What Learning Systems do Intelligent Agents Need? Complementary Learning Systems Theory Updated", Trends in Cognitive Sciences, Vol. 20, No. 7: 512-534, 2016.*

海马子区域工作原理

- 海马体学习系统实现模式选择和模式分离。新的内嗅皮质(ERC)模式激活一组以前未提交的齿状回（DG）神经元，图中显示红色，这些神经元可能是相对年轻的神经元，通过神经发生创建。这些神经元，反过来，通过大的“引爆突触”选择CA3中的神经元的随机子集。
- CA1和内嗅皮质（ERC）之间，以及内嗅皮质（ERC）和新皮质之间的双向投影，支持内嗅皮质(ERC)和新皮质模式的可逆CA1表示的形成和解码，并允许重复计算。



意　识

意识的起源与本质是最重大的科学问题之一。在智能科学中，意识问题具有特别的挑战意义。存在如何决定意识，客观世界如何反映到主观世界中去，既是哲学研究的主题，也是当代自然科学研究的重要课题。意识涉及知觉、注意、记忆、表征、思维、语言等高级认知过程，其核心是觉知(awareness)。近年来，由于认知科学、神经科学和计算机科学的发展，特别是新的无损伤性实验技术的出现，意识的研究再度被提到日程上来，并且开始成为众多学科共同研究的热点。在21世纪，意识问题将是智能科学力图攻克的堡垒之一。

意 识

- 当代著名思想家丹尼特（D.C.Dennett）认为，“人类的意识大概是最后一个难解的谜。……对意识，我们至今如坠五里云雾中，时至今日，意识是唯一常常使最睿智的思想家张口结舌、思维混乱的论题。”在人类已建立的众多概念与范畴体系中，意识是最为混乱的概念之一。

意识的定义

意识是指大脑对认知、情感和意志等心理过程的觉知、调节或控制。”

其中，认知过程具体包括注意、感知、记忆、想象、分析、综合、抽象、概括、判断、推理等心理操作过程。

法伯的意识观

法伯（I.B.Farber）等人在其《意识与神经科学---哲学与理论问题》一文中，从三个层次讨论了意识概念:

- 第一个层次是“意识觉察” ——包括感觉觉察、概括性觉察、元认知觉察和有意识回忆等四种。
- 第二个层次是“较高级的官能” ——不仅能被动地感知和觉察信息，还具有注意、推理和自我控制等较高级的官能(即还具有能动作用)。
- 第三个层次是“意识状态” ——可理解为一个人正在进行的心理活动。

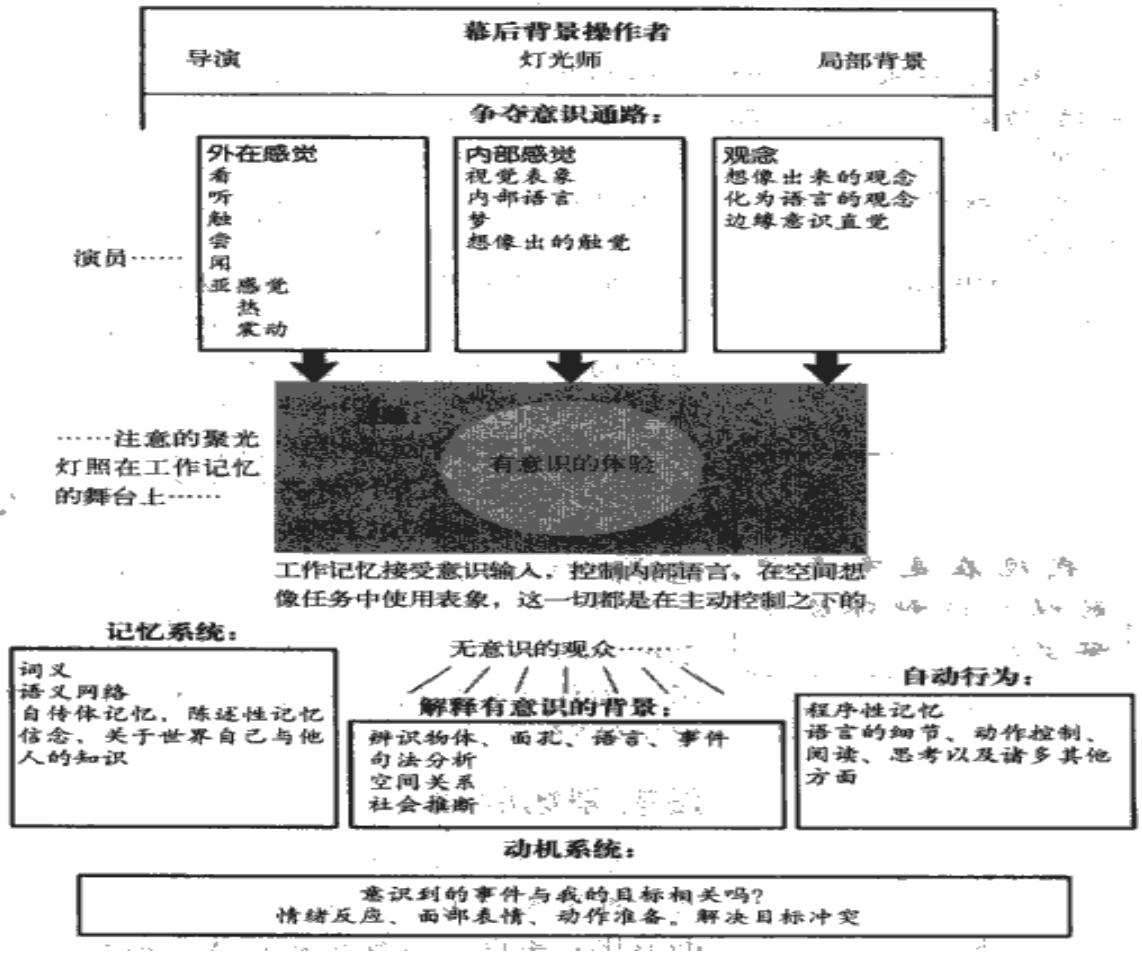
还原论的意识观

- 诺贝尔奖获得者，DNA双螺旋结构的提出者克里克(F. Crick)是这方面的典型代表之一。他认为意识问题是整个神经系统高级功能中的关键问题，1994年出版了一本高级科普书，名为“The Astonishing Hypothesis”(惊人的假设)，副标题为“用科学方法探索灵魂”。他大胆地提出了一个基于“还原论”的“惊人的假说”。
- 认为“人的精神活动完全由神经细胞、胶质细胞的行为和构成及影响它们的原子、离子和分子的性质所决定”。他坚信，意识这个心理学的难题，可以用神经科学的方法来解决。

剧场假设意识理论

- 关于意识问题，最经典的一个假设即所谓“剧场中的亮点”隐喻。在这一个隐喻中，把多个感觉输入综合成一个有意识的经验，比拟为在黑暗的剧场内舞台上有聚光灯打出一个光亮点照到某个地方，然后传播给大量的无意识的观众。在认知科学中，关于意识和选择性注意的假设多数来自于这个基本的隐喻。巴尔(Baar B J)是“剧场隐喻”的最主要的继承和发扬光大者。
- 意识的“剧场假设”隐含着，在舞台上同时有许多角色在演出，正像人脑同时接受内外感受器的多种刺激，但是只有少量角色接收聚光灯的照射，这中间有个选择问题，而且聚光灯不是停留在一个地方、一个角色身上，而是随着时间流动，观众代表着脑的无意识的部分。

Baars全局工作空间意识理论



Baars全局工作空间意识理论

GWT模型要点：

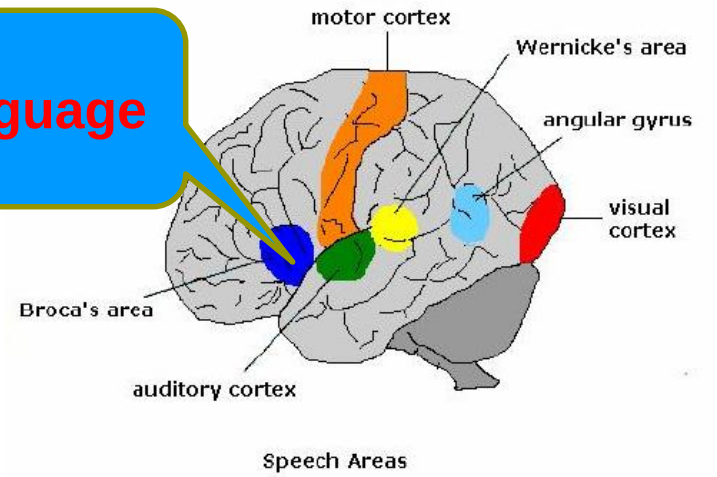
- 只有少数事件被意识到；
- 聚焦的意识类似起到亮点的作用，意识的内容被限制的亮点之内；；
- 舞台、后台与观众的互动是以一个全局全局工作空间结构为基础。

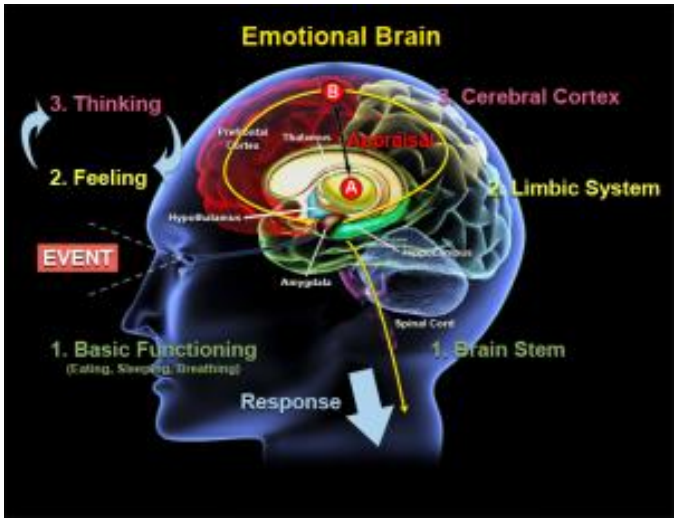
微管假说意识理论

- 微管假说以朋罗塞(Penrose)最为著名。他是当代著名的数理科学家。认为意识起源于神经元中特殊的蛋白质结构(微管)的量子物理过程。神经元的细胞组织中细胞骨架在传递信息上起重要作用，细胞骨架是由“微管”构成，由于其空间尺度很小，应当用量子力学来考虑，电磁波有可能在其中传播。
- 人们认为从意识角度考虑，这个空间尺度太小，层次太低，从系统论角度考虑用这么小的空间尺度和低层次的角度，无法对如此复杂和高层次的功能做出完美的解释。

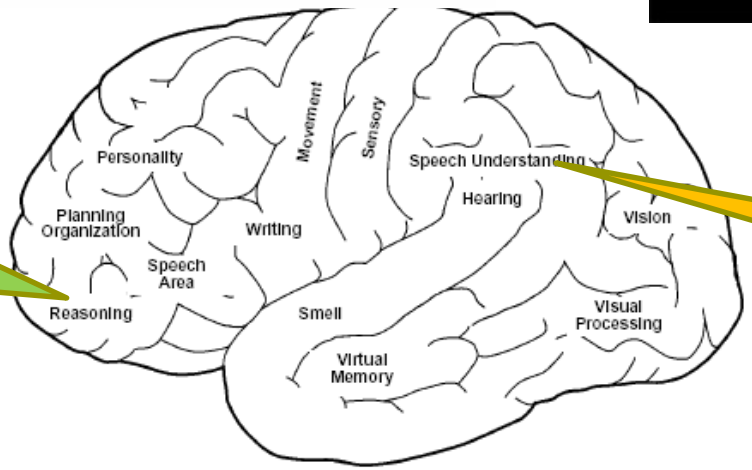
高级认知功能

Language





Thinking

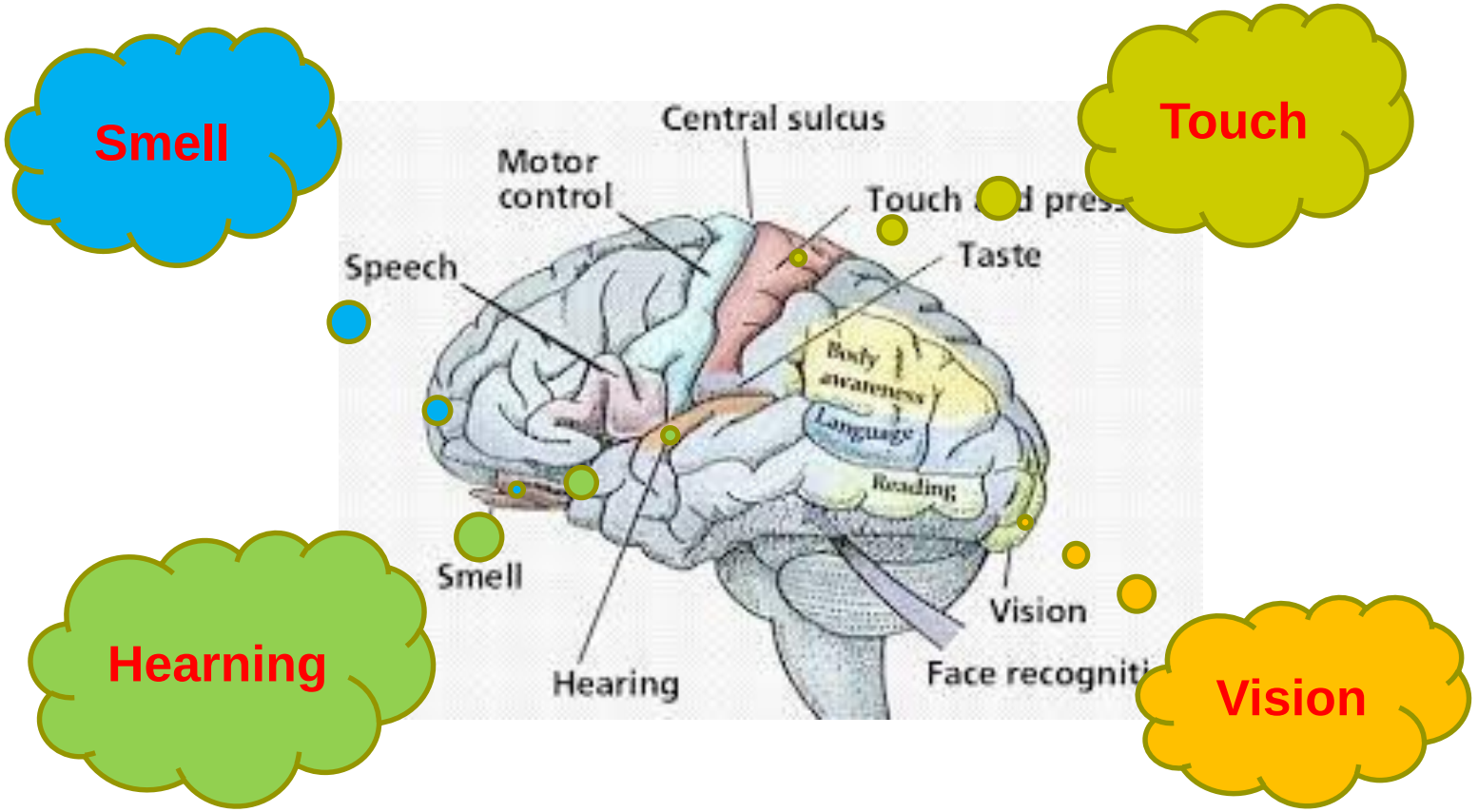


Learning

感知Sensory

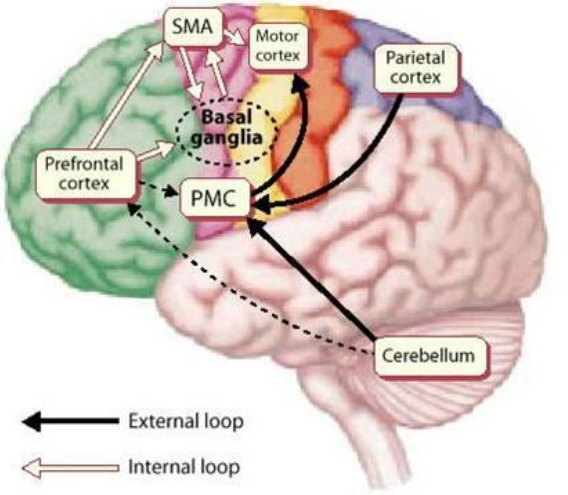
- **Visual module**: From lateral geniculate nucleus (LGN) neuron send their signals through V1,V2, V3 and V4 and onward to many areas of the temporal lobe.
- **Hearing module**: From ear, to the brainstem, to subcortical nuclei, and to cortex..
- **Touch module**: Touch is the general term of mechanical stimulation such as contact, sliding, pressure and so on.
- **Smell module**: The sense of smell is a kind of feeling. It is involved in the sensory system of the two sensory system, the olfactory nerve system and the nasal trigeminal nerve system.
- **Sensory buffers**: Each of the classical senses is believed to have a brief storage ability called a sensory buffer.

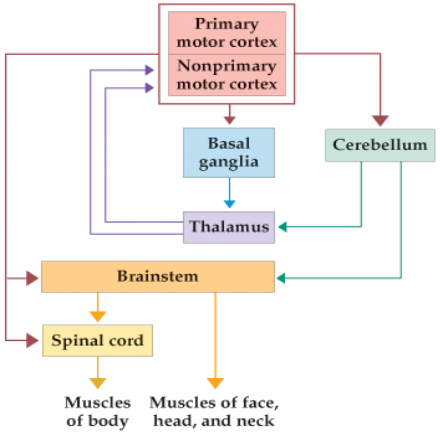
感知Sensory


Smell
Touch
Central sulcus
Motor control
Speech
Taste
Body awareness
Language
Reading
Smell
Vision
Hearing
Face recogniti
Hearning
Vision

运动动作Motor Action

- **Action selection**: First is atomic action selection, i.e., select related atomic action from action library. Then selected atomic actions are composed together using a planning strategy.
- **Response output**: The motor hierarchy begins with general goals.





CAM的特点

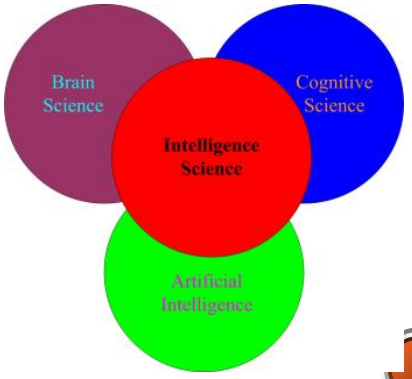
CAM-**C**onsciousness **a**nd **M**emory Model is

A new mind modeling for human cognitive activities

Characteristics of CAM

- Memory based Mind Model;
- Consciousness-centered Cognitive Activities;
- Action planning based way to arrange different cognitive function modules to perform cognitive activities;

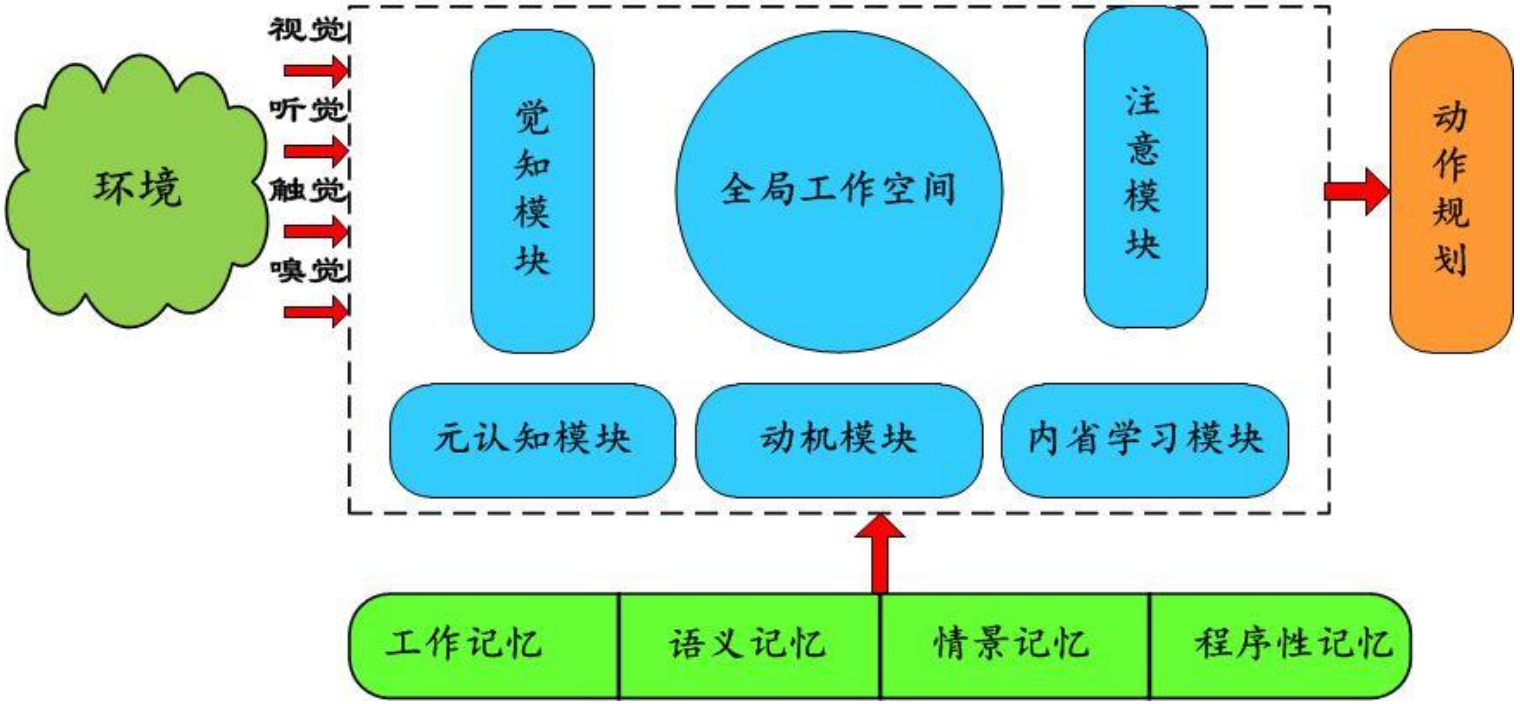
内容提要



- 概述
- 心智模型
- 机器意识系统
- 脑机融合
- 脑认知图

机器意识系统

心智模型CAM的意识子系统，它由全局工作空间、觉知、注意、动机、元认知、内省学习模块构成。



觉知模块Awareness Module

- Awareness module begins with the input of external stimuli, and the primary features of the sensing system are activated. The output signal is sent to the sensory memory, where a higher level of functional detectors are used for more abstract entities, such as objects, categories, actions, events, etc.. The resulting perception is sent to the workspace, where local connections short episodic memory and declarative memory will mark thread.

环境感知

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The brain machine collaborative awareness model is defined as 2-tuples: {Element, Relation}, where Element of awareness is described as follows:

a) Who: describes the existence of agent and identity the role, answer question who is participating?

b) What: shows agent's actions and abilities, answer question what are they doing? And what can they do? Also can show intentions to answer question what are they going to do?

c) Where: indicates the location of agents, answer question where are they?

d) When: shows the time point of agent behavior, answer question when can action execute?

基本关系

- Task relationships define task decomposition and composition relationships. Task involves activities with a clear and unique role attribute
- Role relationships describe the role relationship of agents in the multi-agent activities.
- Operation relationships describe the operation set of agent.
- Activity relationships describe activity of the role at a time.
- Cooperation relationships describe the interactions between agents.

注意模块

- Detection of new events is an important feature of any signal classification method. Because we are not able to train all the data that may be encountered in the machine learning system, it becomes very important to distinguish known and unknown object information in the test. Novelty detection is a very challenging task, which can be found in a complex, dynamic environment of the novel, interesting

全局工作空间模块

- The global workspace module is in the working memory area, in which different systems can perform their activities. Global means that the symbols in this memory are distributed and passed through a large number of processors.
- The competition of the global working space selects the most outstanding, the most relevant, the most important and the most urgent affair, their content becomes the content of consciousness. Then, the contents of the consciousness are broadcasted to the whole space, and the action selection phase is initiated.

CAM的动机学习

- 1. Observe $\mathbf{O}_{S(t)}$ from $\mathbf{S}_{(t)}$ using the observation function
- 2. Subtract $\mathbf{S}_{(t)}$ - $\mathbf{S}_{(t')}$ using the difference function
- 3. Compose $\mathbf{E}_{S(t)}$ using the event function
- 4. Look for **N**(t) using introspective search
- 5. Repeat (for each $N_i(t) \in N(t)$)
- 6. Repeat (for each $I_j(t) \in \mathbf{I}(t)$)
- 7. Attention = max $I_j(t)$
- 8. Create a Motivation by Attention.

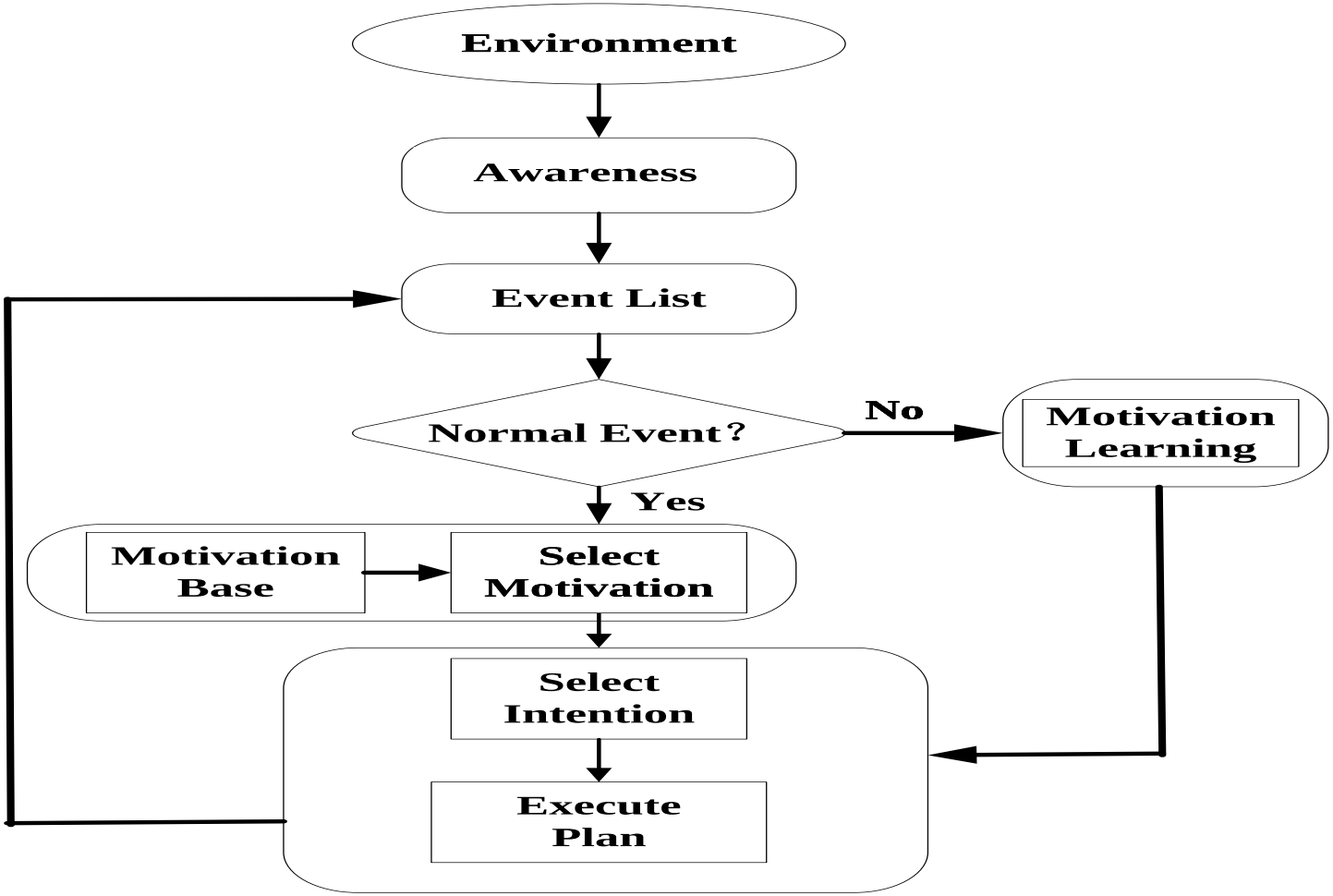
动机规则

- Motivation could be represented as a 3-tuples {*N, G,I*}, where *N* means needs, *G* is goal, *I* means the motivation intensity. A motivation is activated by motivational rules which structure has following format:

$$R=(P, D, \text{Strength}(P|D))$$

- where, *P* indicates the conditions of rule activation; *D* is a set of actions for the motivation; Strength(*P*|*D*) is a value within interval [0,1].

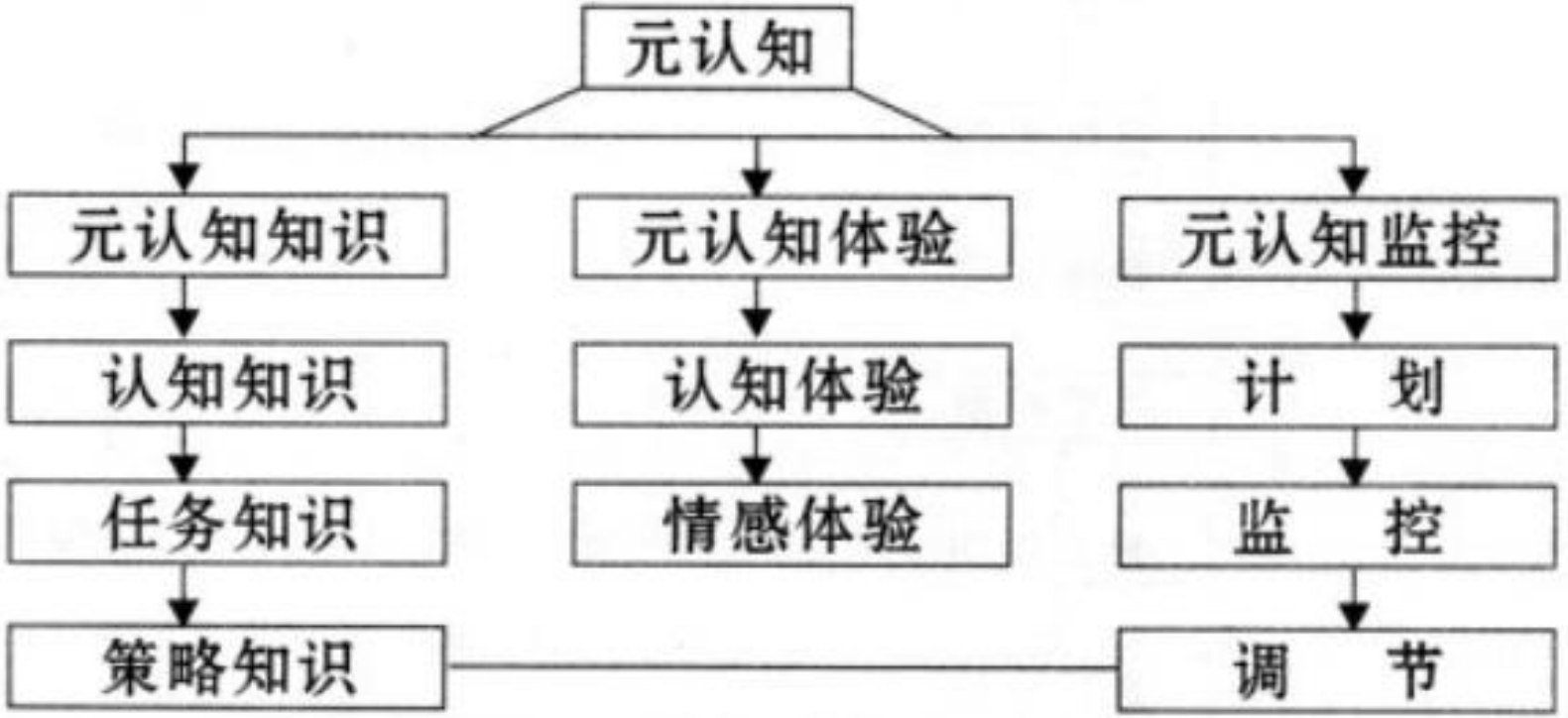
动机模块


Environment
Awareness
Event List
Normal Event?
No
Motivation Learning
Yes
Motivation Base
Select Motivation
Select Intention
Execute Plan

元认知模块

- In mind model CAM, metacognition provides the cognition and monitoring of thinking activity and learning activity of the agent, which the core is knowledge about cognition and control of cognition. Metacognition module has the function of metacognitive knowledge, metacognitive self-regulation control and metacognitive experience.

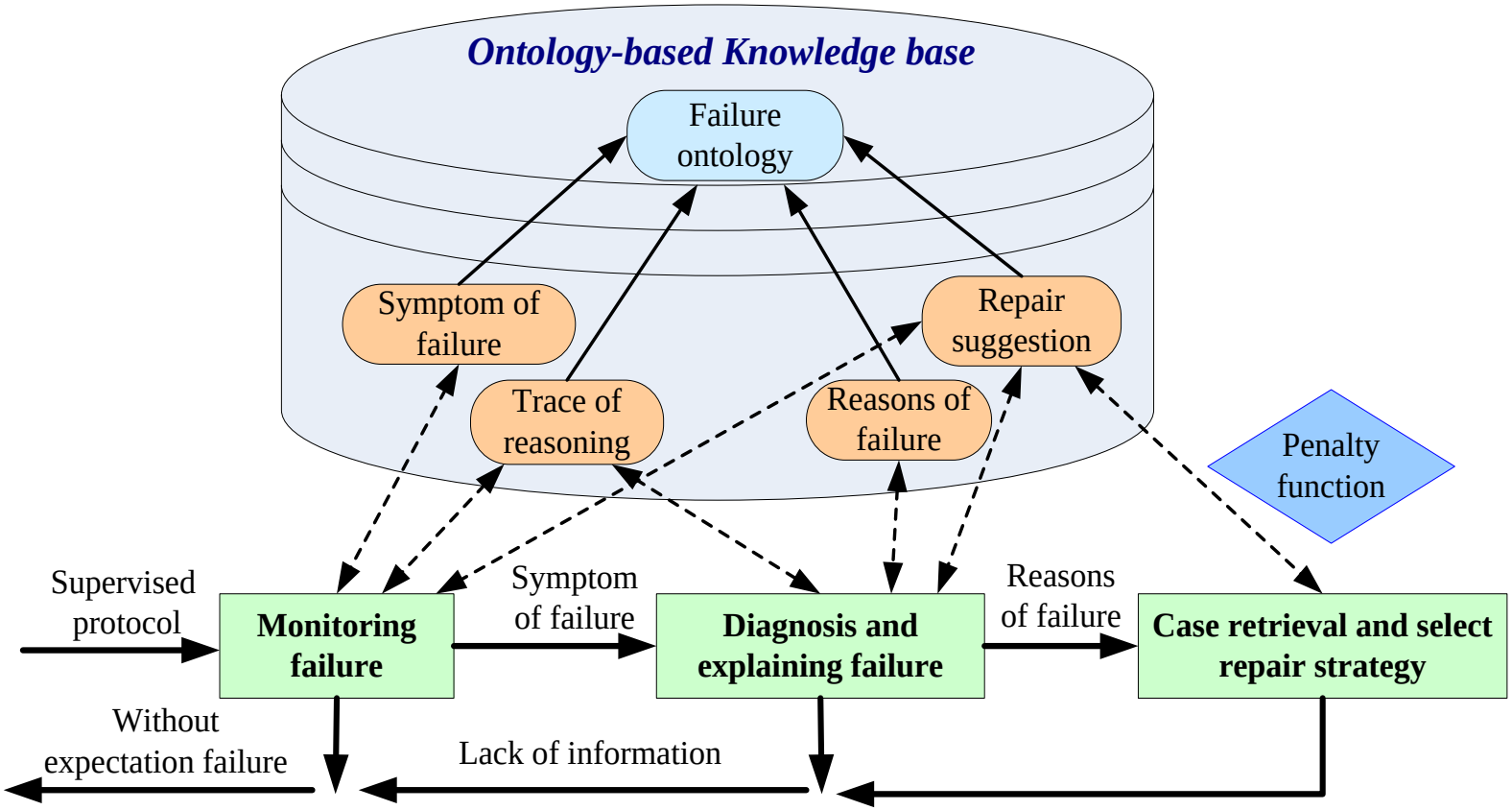
元认知模块结构



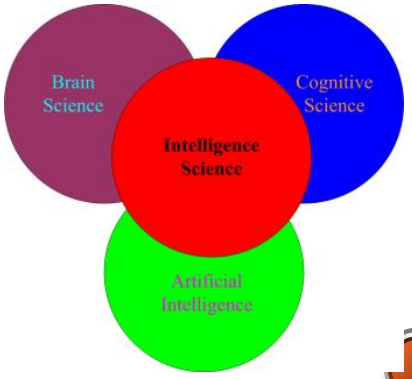
内省模块

- The introspection refers to investigating a person's own thought or emotion, i.e. self-observation; it also refers to observing sensation and perception experience under the control of experiment condition.
- By checking and caring about knowledge processing and reasoning method of intelligence system itself and finding out problems from failure or poor efficiency, the introspection learning forms its own learning goal and then improves the method solving problems.

内省模块


Ontology-based Knowledge base
Failure ontology
Symptom of failure
Trace of reasoning
Reasons of failure
Repair suggestion
Penalty function
Supervised protocol
Monitoring failure
Symptom of failure
Diagnosis and explaining failure
Reasons of failure
Case retrieval and select repair strategy
Without expectation failure
Lack of information

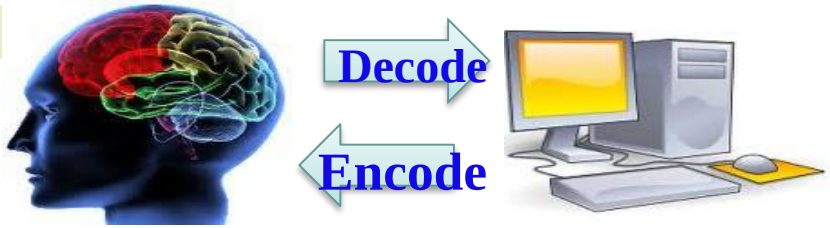
内容提要



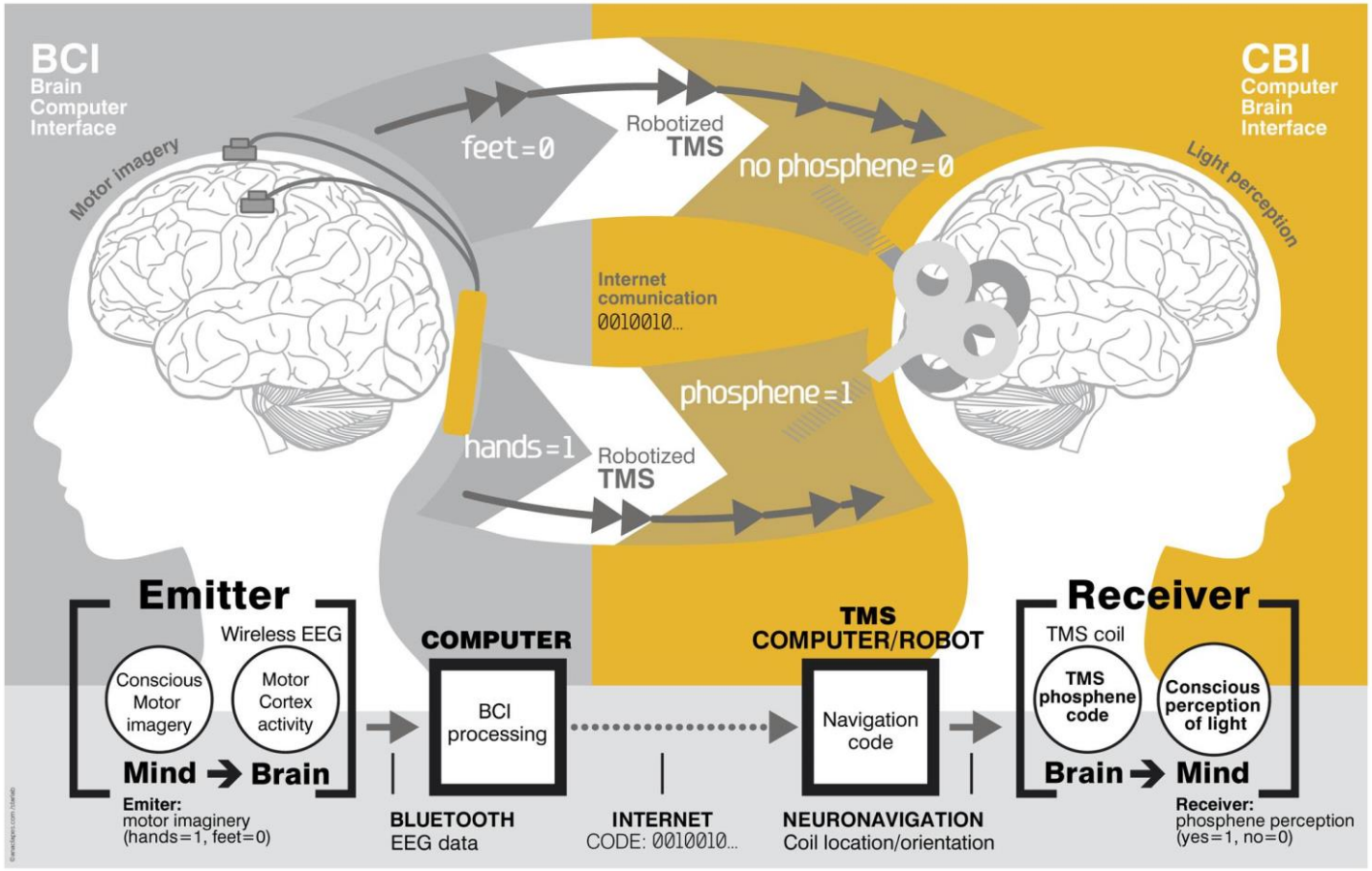
- 概述
- 心智模型
- 机器意识系统
- 脑机融合
- 结束语

脑机 I^3

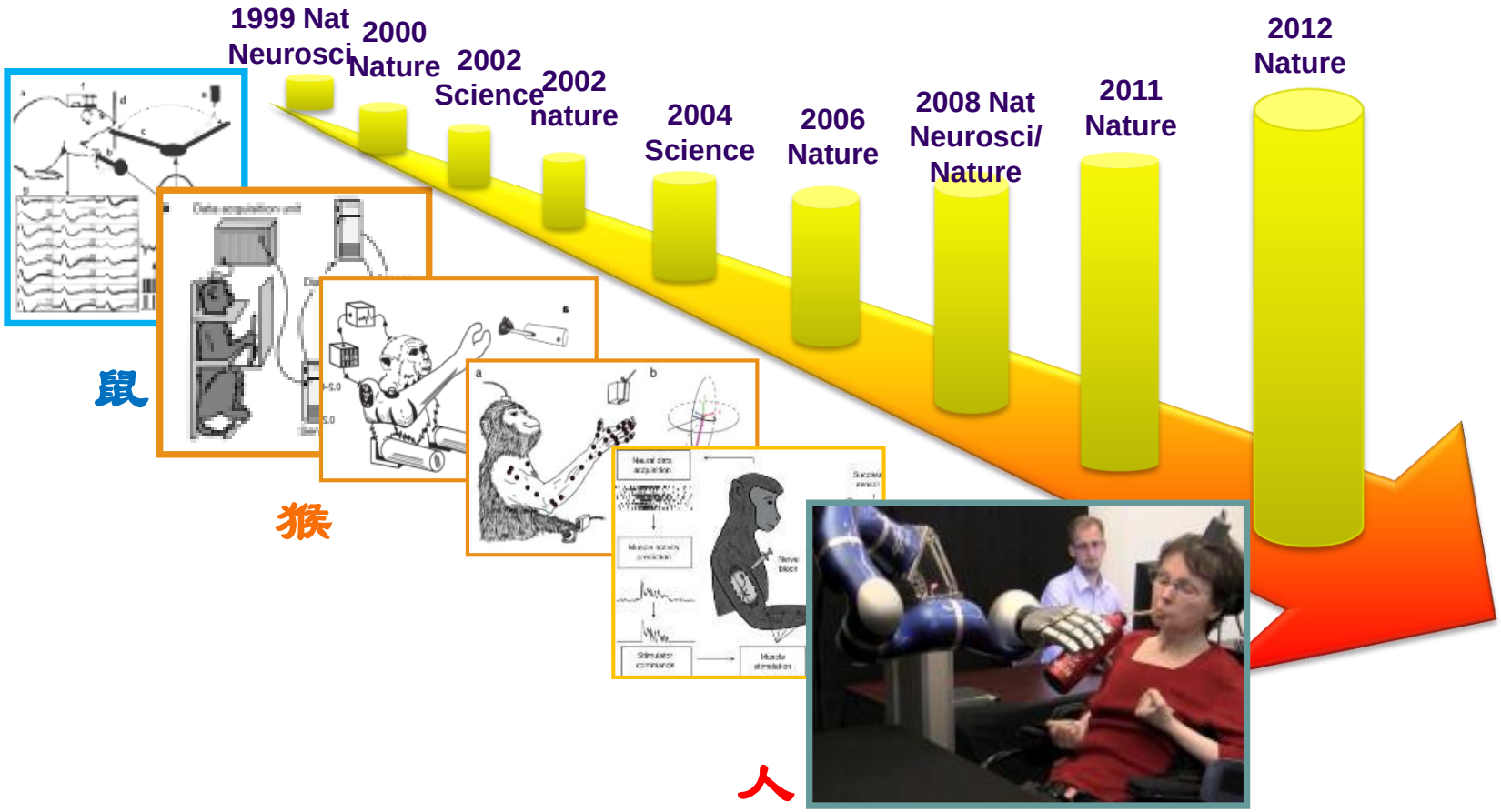
- Integration
- Interaction
- Interface



脑机接口


BCI
Brain
Computer
Interface
Motor imagery
feet=0
Robotized
TMS
no phosphene=0
CBI
Computer
Brain
Interface
Light perception
Internet
comunication
0010010...
phosphene=1
hands=1
Robotized
TMS
Emitter
Wireless EEG
Conscious
Motor
imagery
Motor
Cortex
activity
Mind → Brain
Emiter:
motor imaginery
(hands=1, feet=0)
COMPUTER
BCI
processing
BLUETOOTH
EEG data
INTERNET
CODE: 0010010...
TMS
COMPUTER/ROBOT
Navigation
code
NEURONAVIGATION
Coil location/orientation
Receiver
TMS coil
TMS
phosphene
code
Conscious
perception
of light
Brain → Mind
Receiver:
phosphene perception
(yes=1, no=0)

脑机接口


1999 Nat Neurosci
2000 Nature
2002 Science
2002 nature
2004 Science
2006 Nature
2008 Nat Neurosci/ Nature
2011 Nature
2012 Nature
鼠
猴
人

Bloomberg

马斯克 Neuralink

- On March 28, 2017, SpaceX and Tesla CEO Elon Musk is backing a brain-computer interface venture called Neuralink Corp， a company devoted to developing neural implants. It is a closer merger of biological intelligence and digital intelligence

Bloomberg

浸润式脑机接口

- **On June 1, 2018, Microsoft CEO Satya Nadella revealed the news at the eighth "Ability" conference in Microsoft, researchers are working on whether brain implants can enhance human intelligence to increase the help of people with disabilities**

脑机融合的感知与认知计算理论和方法

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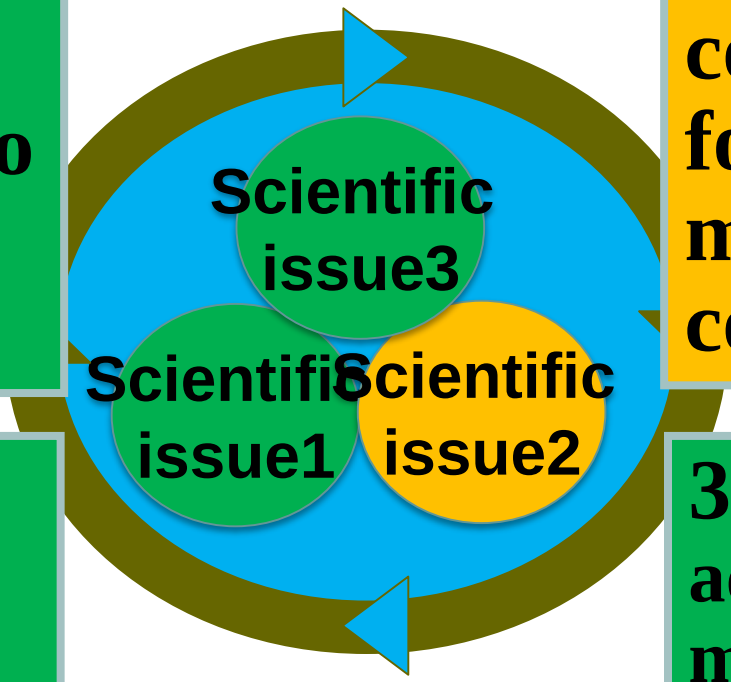
1. Brain information representation, encode and decode

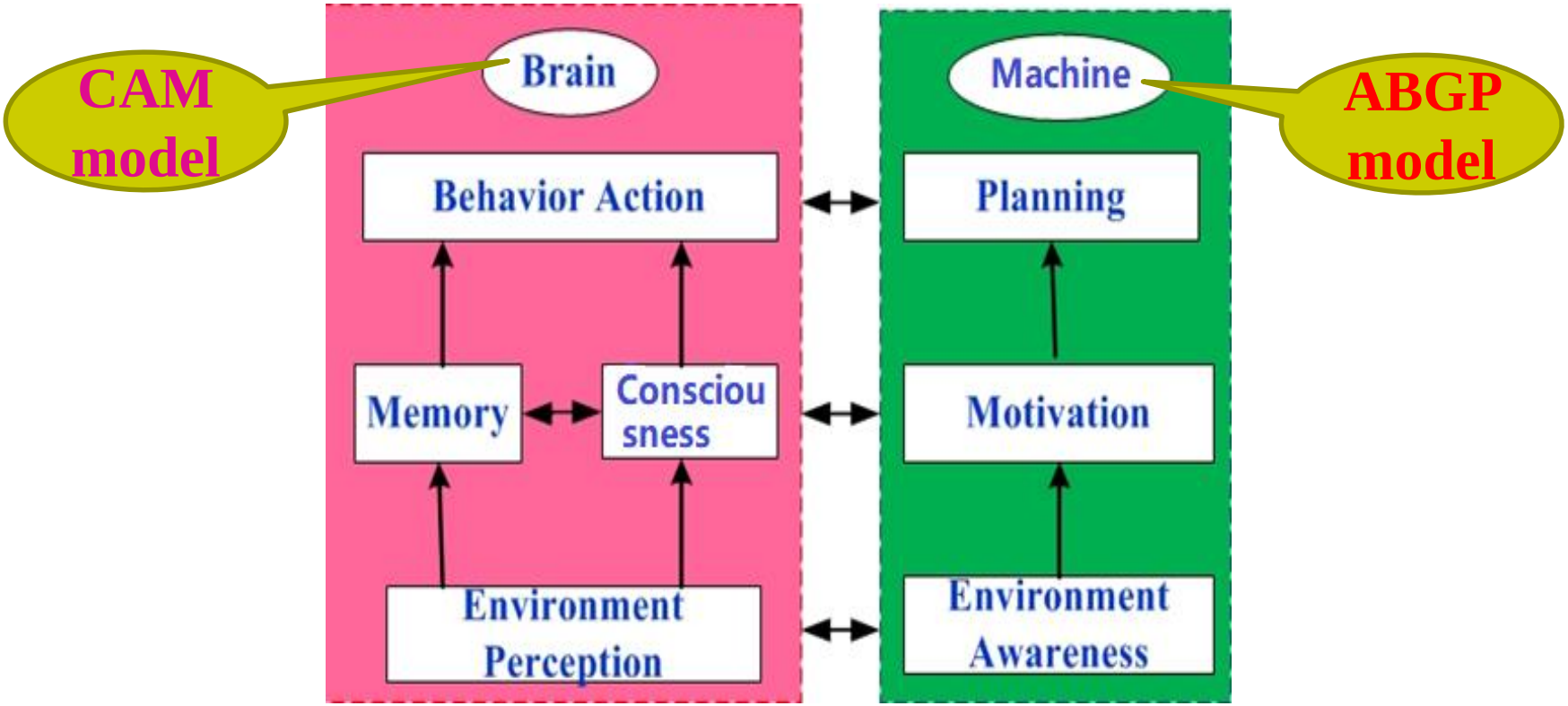
2. Cognitive computing for brain-machine collaboration



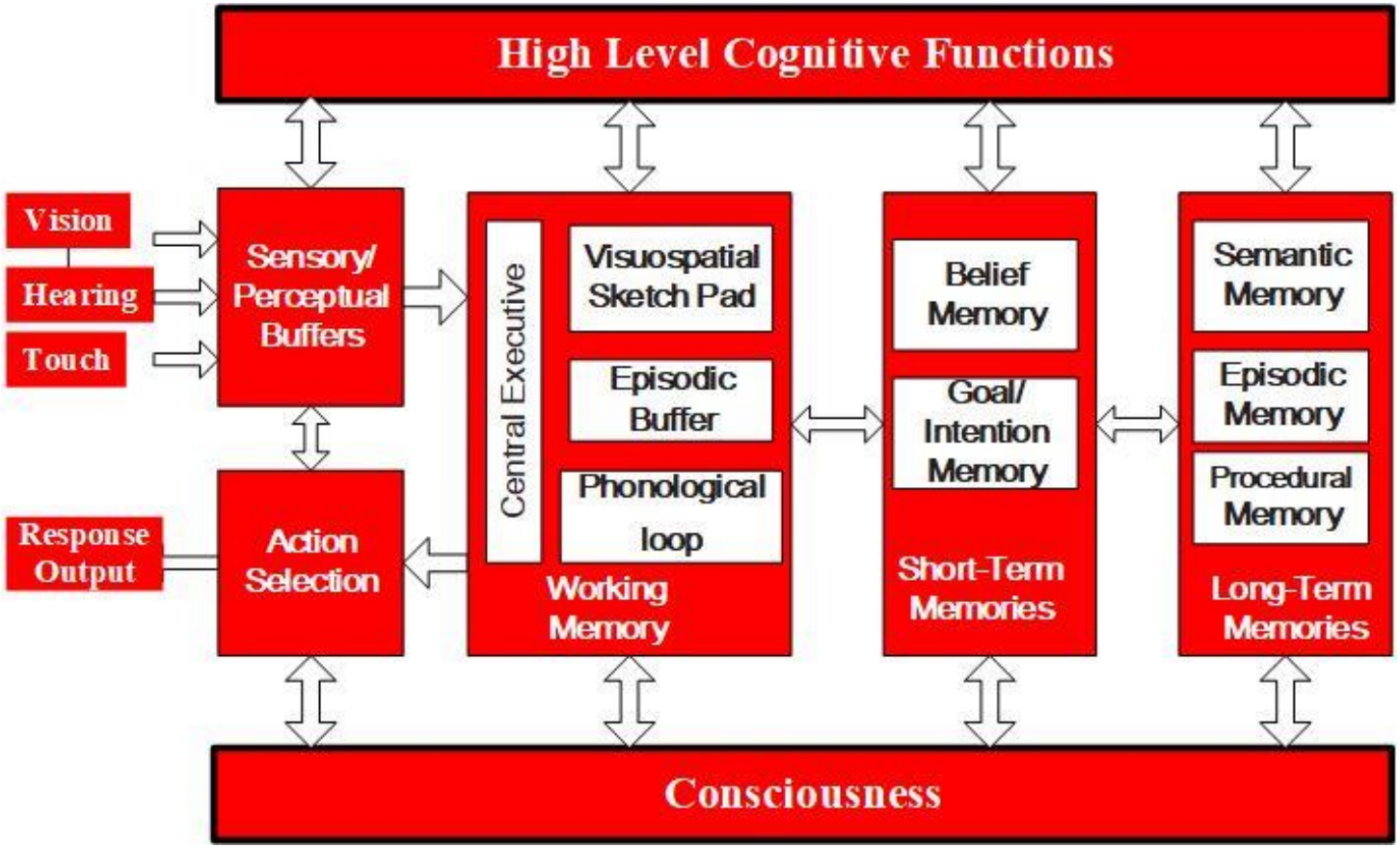
4. Experimental platforms and Application verification

3. Mutual adaptation and motor functional reconstruction

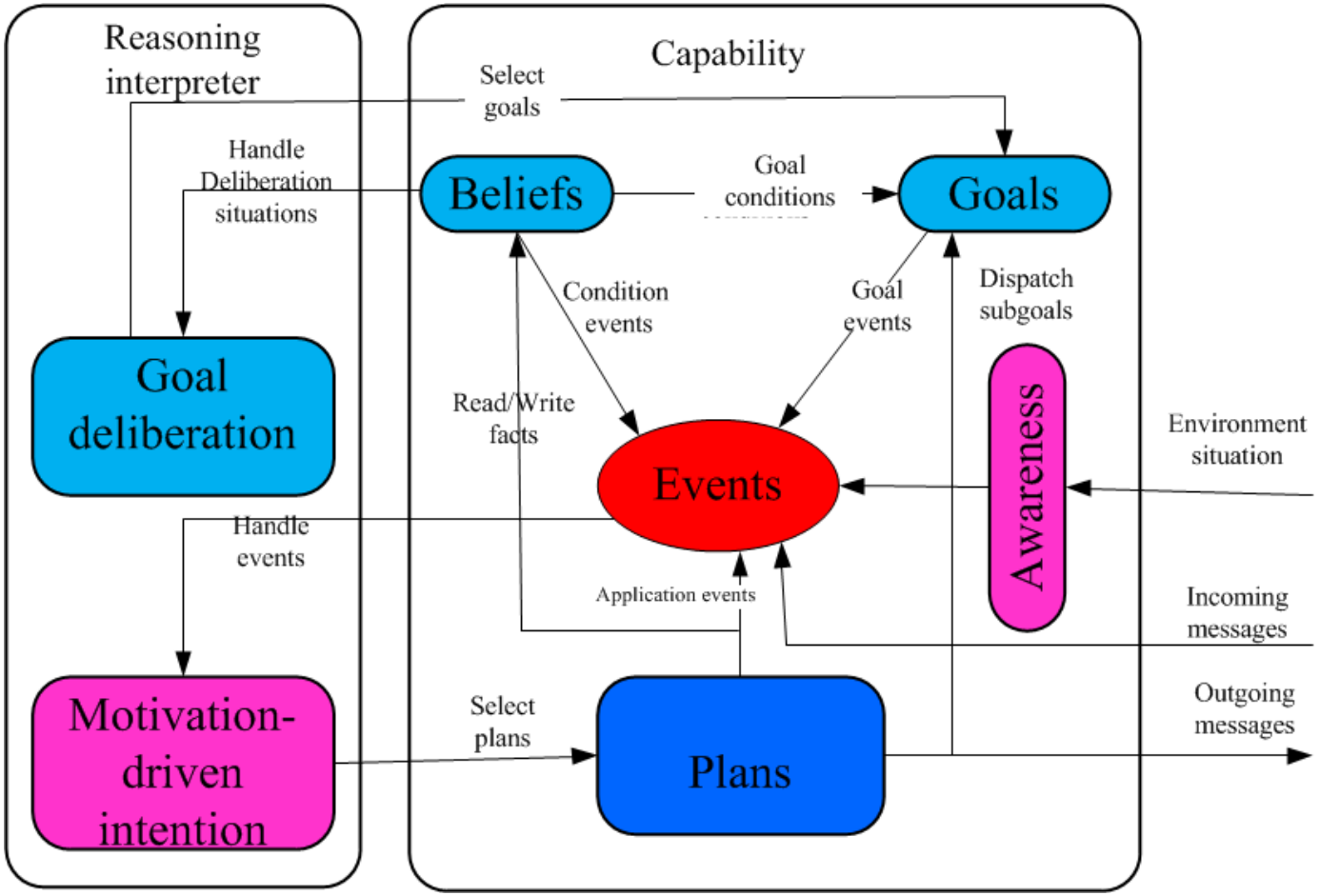
脑机融合的认知模型


CAM model
Brain
Behavior Action
Memory
Consciou sness
Environment Perception
Machine
Planning
Motivation
Environment Awareness
ABGP model

心智模型 CAM



ABGP 模型



联合意图

- In the joint-intention theory, a team is defined as “a set of agents having a shared objective and a shared mental state.”
- Agent joint intention means an agent wants to achieve a formula, which corresponds to the agent’s goal.
- A joint intention to perform a particular action is a joint commitment to enter a future state wherein the agents mutually believe the collaborative action is imminent just before they perform it

单个意图

- **1984 Bratman, BDI**
- **1990 Cohen and Levesque, intention model.**
- **1990 Pollack, intention model**
- **1988/1989 Werner, intention model,**

  Social roleRrol = <Irol, Srol, Vrol>

联合意图

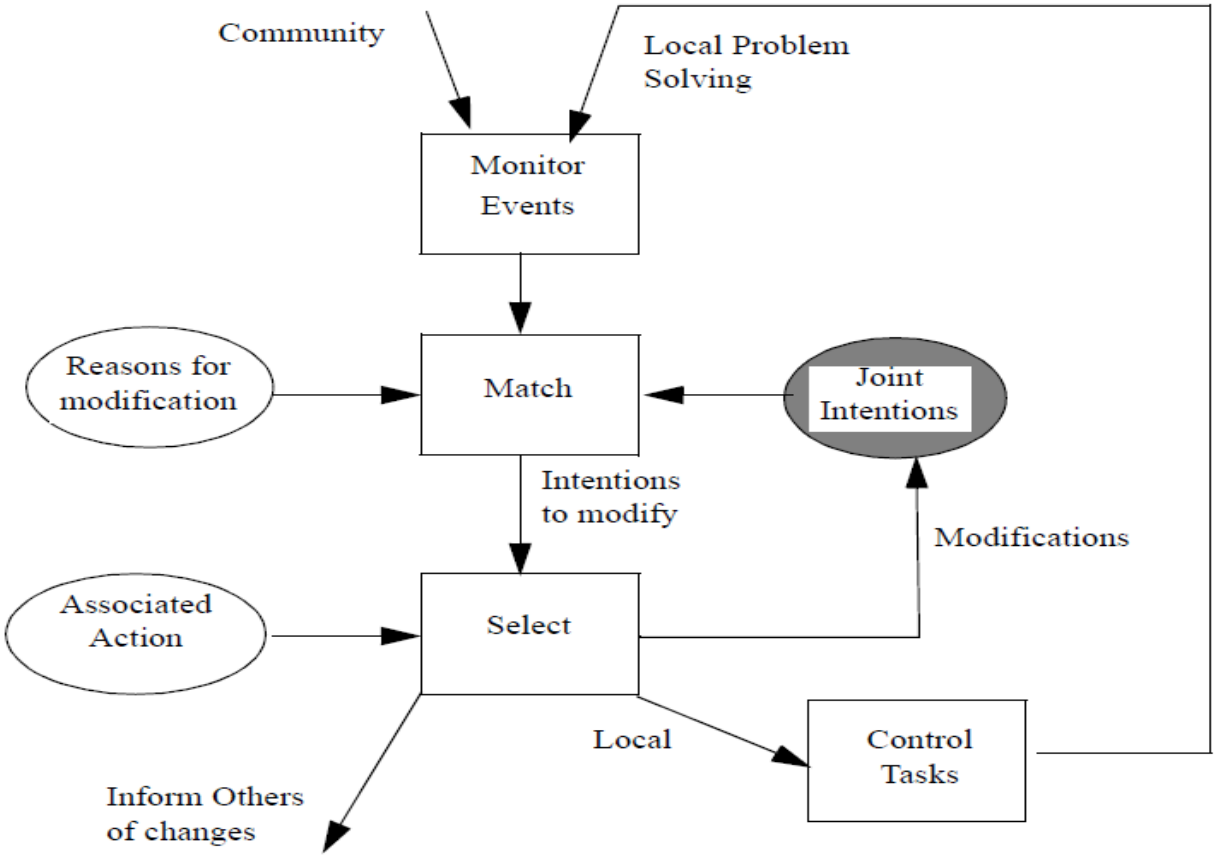
- 1989 Conte, Group Mind
- 1990 Searle, collective intentions
- 1990 Grosz and Sidner, Shared Plan
- 1988 Tuomela and Miller, we-intentions
- 1990 Rao *et al. Social Plans*
- 1990 Singh Group Intentions

联合意图

1992 Jennings claimed the need to describe collectives as well as individuals.

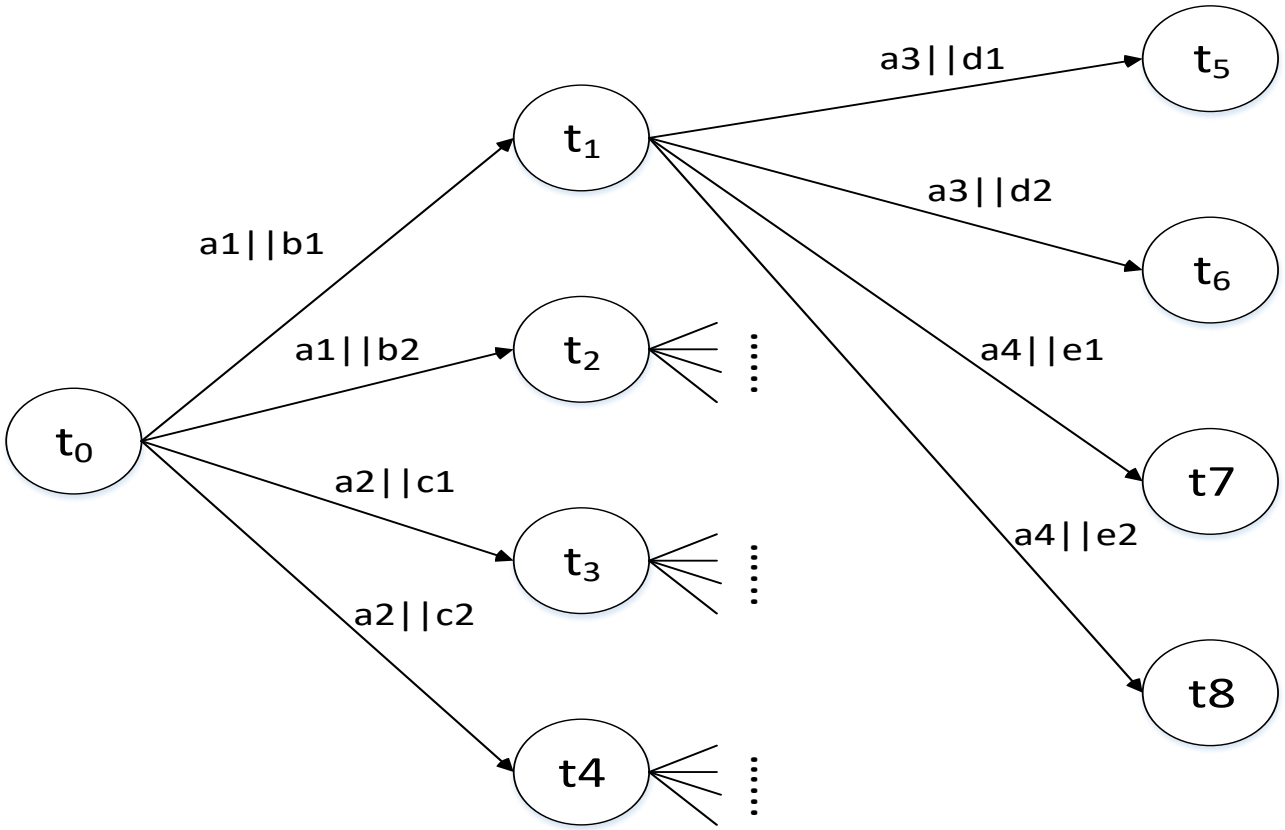
- agents must agree on a common goal.
- agents must agree they wish to collaborate to achieve their shared objective.
- agents must agree a common means of reaching their objective.
- action inter-dependencies exist and must be catered for

GRATE*：知识级协作系统



Nicholas Robert Jennings. Joint Intentions as a Model of Multi-Agent Cooperationin Complex Dynamic Environments. University of London, 1992.

联合意图


t0
t1
t2
t3
t4
t5
t6
t7
t8
a1||b1
a1||b2
a2||c1
a2||c2
a3||d1
a3||d2
a4||e1
a4||e2

描述逻辑

Description Logic

- Concepts and Role
- Tbox——Assertions
- Abox——Instance
- Reasoning mechanism in terms of Tbox and Abox

描述逻辑

K

B

TBox(Scheme)

Man = Human ⊓ Male

Happy-father = Human ⊓ ∃ Has-child. Female⊓ …

Abox(Data)

John: Happy-father

<John, Mary> : Has-child

Reasoning

Interface

动态描述逻辑

- Concept name：$C_1, C_2, \ldots$；
- Role name：$R_1, R_2, \ldots$；
- Individual constant：$a, b, c, \ldots$；
- Individual variable：$x, y, z, \ldots$；
- Concept operation：$\neg, \sqcap, \sqcup, \exists, \forall$；
- Axiom operation：$\neg, \wedge, \rightarrow\forall$；
- Action：$A_1, A_2, \ldots$；
- Action constraction ： ； (composition) ， ∪ (alternation)，* (repeat)，？(test)；
- Action variable：$\alpha,\beta, \ldots$；
- Axiom variable：$\varphi, \psi, \Box, \ldots$；
- State variable：$u, v, w, \ldots$；

动态描述逻辑

***Concepts in DDL are defined as the following*:**

- **(1) *Primitive concept P, top* $\top$ *and bottom* $\bot$ *are concepts*.**
- **(2) $\neg C$, $C \sqcap D$, $C \sqcup D$ *are concepts*.**
- **(3) $\exists R.C$, $\forall R.C$ *are concepts*.**

动态描述逻辑

An action description is the form

$$A(x_1,\ldots,x_n)=(P_A,E_A)$$

where

(1) *A is the action name.*

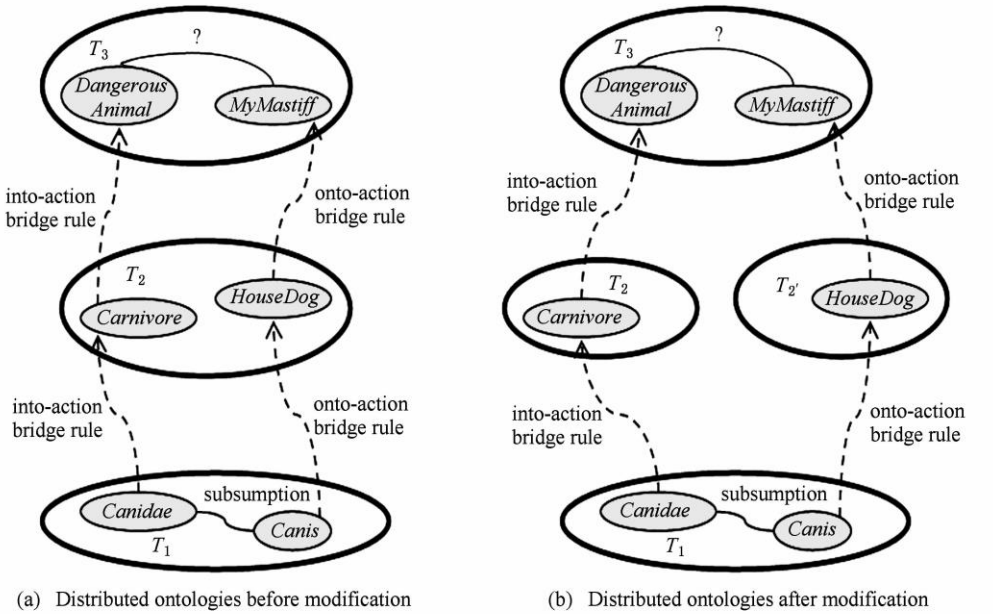
(2) $x_1, \ldots, x_n$ *are individual variables, which denote the objects the action operate on.*

(3) P_A *is the set of preconditions, which must be satisfied before the action is executed.*

(4) E_A *is the set of results, which denote the effects of the action.*

分布式动态描述逻辑

Bridge rules provide an important mechanism describing semantic mapping and propagating knowledge for distributed dynamic description logics(D3L). The current research fo…s which only conta…



Xiaofei Zhao, Dongping Tian, Limin Chen, Zhongzhi. Reasoning Theory for D3L with Compositional Bridge Rules. IFIP IIP 2012, 2012, 106-115.

分布式动态描述逻辑

Each BR_{ij} is a collection of bridge rules in direction from T_i to T_j which are of four forms:

$$i: C \xrightarrow{\sqsubseteq} j: E \quad \text{(into-concept (relation) bridge rule)};$$
$$i: C \xrightarrow{\sqsupseteq} j: E \quad \text{(onto- concept (relation) bridge rule)};$$
$$i: \alpha \xrightarrow{\sqsubseteq} j: \beta \quad \text{(into-action bridge rule)};$$
$$i: \alpha \xrightarrow{\sqsupseteq} j: \beta \quad \text{(onto-action bridge rule)}.$$

Xiaofei Zhao, Dongping Tian, Limin Chen, Zhongzhi. Reasoning Theory for D3L with Compositional Bridge Rules. IFIP IIP 2012, 2012, 106-115.

协同决策

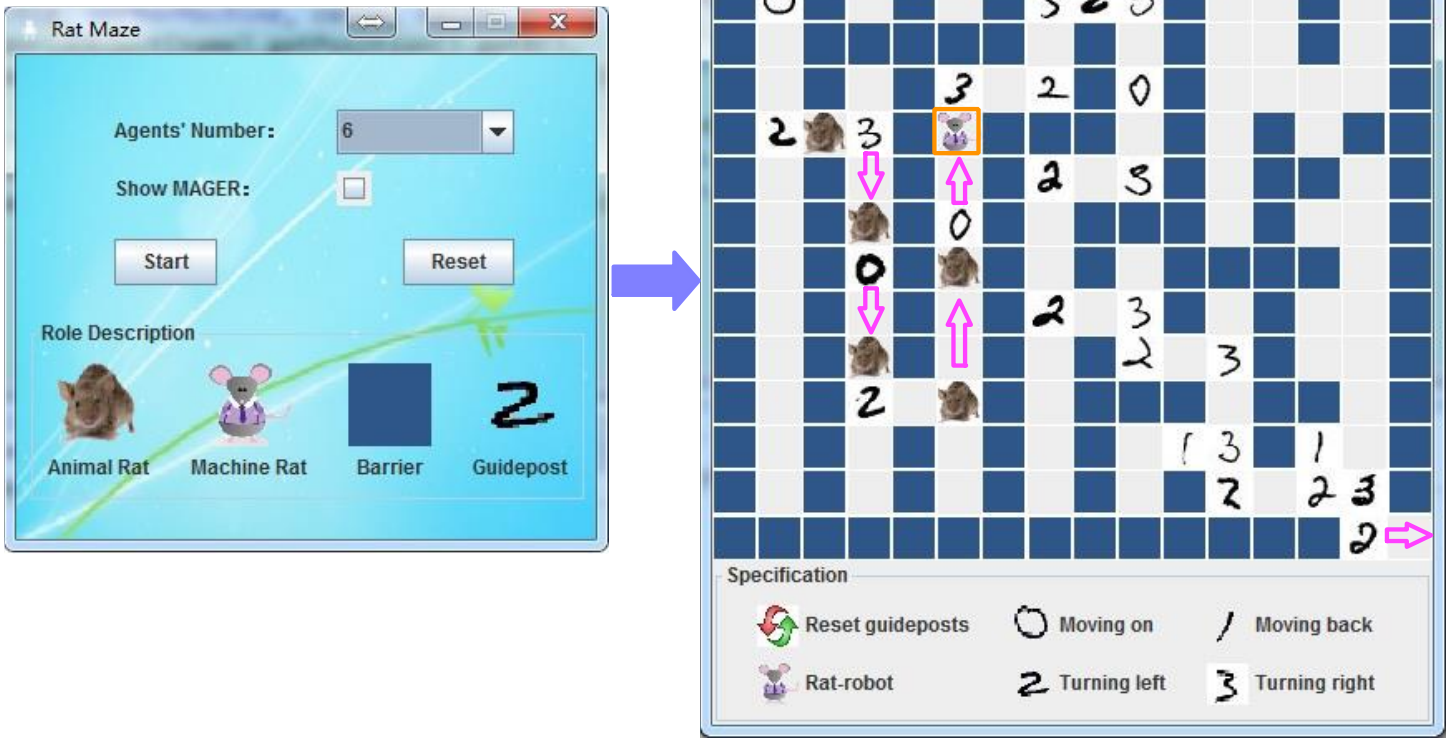
INSTITUTE OF COMPUTING TECHNOLOGY

Collaborations occur over time as organizations interact formally and informally through repetitive sequences of negotiation, and commitment development and execution. Under the support of the National Program on Key Basic Research Project (973) we focus on Computational Cognitive Models for Brain–Machine Collaborations:

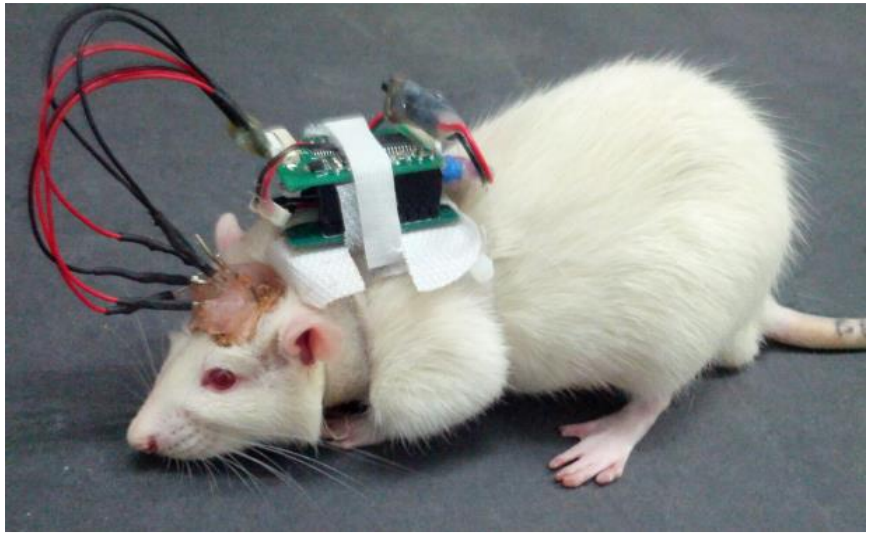
- **Awareness-Based Collaboration**
- **Motivation-Based Collaboration**
- **Joint Intention-Based Collaboration**

Zhongzhi Shi, Jianhua Zhang, Xi Yang, Gang Ma, Baoyuan Qi, Jinpeng Yue. Computational Cognitive Models for Brain-Machine Collaborations. IEEE Intelligent Systems 29(6): 24-31 (2014).

大鼠机器人迷宫仿真

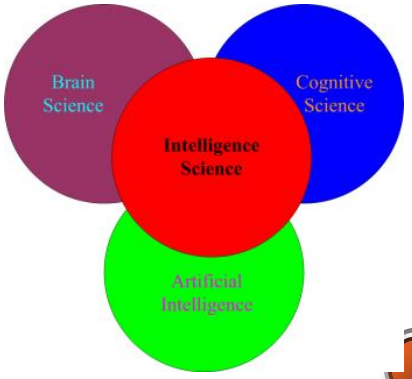

Rat Maze
Agents' Number:
6
Show MAGER:
Start
Reset
Role Description
Animal Rat
Machine Rat
Barrier
Guidepost
Rat Maze Search
Specification
Reset guideposts
Moving on
Moving back
Rat-robot
Turning left
Turning right

大鼠机器人



通过脑机接口技术对大脑施加刺激信号，实现对于大脑活动的调控，控制大鼠的运动方向和行进路线，使大鼠成为“动物机器人”。将控制电极通过手术植入大鼠大脑的特定区域，通过无线通讯设备，可以远程遥控大鼠在复杂环境中前进、转向，甚至上下爬坡等，也可以同时控制多只大鼠完成协同搜索工作。

内容提要

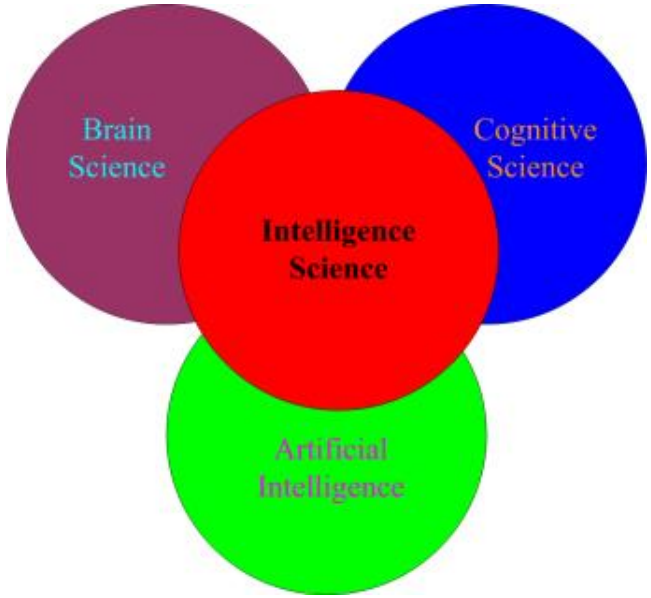


- 概述
- 心智模型
- 机器意识系统
- 脑机融合
- 结束语

结束语

- 心智模型CAM是智能系统通用框架
- 机器意识系统是实现智能系统自动控制的关键
- 脑机融合是实现智能系统的重要途径。

Thank You



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