Brain Machine Integration

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Contents Outline

Introduction

Environment Awareness

Motivation Driven Reasoning

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Intelligence Science

Intelligence science is an interdisciplinary subject on basic theory and technology of intelligence, mainly including brain science, cognitive science, artificial intelligence and others.

- **Brain science** explores the essence of brain, research on the principle and model of natural intelligence in molecular, cell and behavior level.
- **Cognitive science** studies human mental activity, such as perception, learning, memory, thinking, consciousness etc.
- **Artificial intelligence** attempts simulation, extension and expansion of human intelligence using artificial methodology and technology
Human-Level AI

The long-term goal of Artificial Intelligence is human-level Artificial Intelligence.


Intelligence Science Is The Road To Human-Level Artificial Intelligence
Big Issues

- Signaling in the Nervous System
- Synaptic Plasticity
- Perceptual Representation
- Learning Emergence
- Coding and Retrieval of Memory
- Linguistic Cognition
- Formalizing of Commonsense knowledge and Reasoning
- Nature of Consciousness
- Mind model
- Architecture of Brain-like Computer
Intelligence Science Website

Intelligence science is an interdisciplinary subject which is jointly studied by brain science, cognitive science, artificial intelligence and others. Intelligence science not only to conduct functional simulation of intelligent behavior, but also should research on the mechanism to explore new theory of intelligence, new technologies.

World Scientific publishes book <Intelligence Science> which is Volume 1 of the Series on Intelligence Science. Here is the first chapter introduction.

Focus Highlight

- **Chinese Society for Cognitive Science was formally established**
  

- **Brain-like Intelligent Machines**
  
  Sponsored by Intelligent Science and Technology Online Cooperative Research Center of Ministry of Education, Zhejiang University hosted the second "Intelligence Science and Technology Conference" on November 29, 2011 held in Hangzhou. Zhongzhi Shi was invited to deliver the report on brain-like intelligent machines.

- **The Human Brain Project**

  Henry Markram, coming from Brain Mind Institute, EPFL in Switzerland, is going to organize the human brain project for applying Future and Emerging Technologies (FET) Flagship Programme.

- **John McCarthy**

  John McCarthy, a computer science pioneer, father of AI and Lisp, died October 24, 2011 at his home in Stanford, California.

- **Cognitive Cycle in Mind Model CAM**

2018/7/4

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Series on Intelligence Science

Series on Intelligence Science

Aims and Scope

Intelligence science is an interdisciplinary subject dedicated to joint research on the basic theory and technology of intelligence among the fields of brain science, cognitive science, and artificial intelligence. From the perspective of the sciences of the brain, it conducts research on the basic principles and mechanisms of natural intelligence and the artificial intelligence in the fields of brain sciences, cognitive sciences, and other fields. The common research content of the two sciences is the study of human intelligence, such as perception, learning, memory, thinking, consciousness, etc. In order to implement machine intelligence, artificial intelligence is combined with the simulation, extension, and expansion of human intelligence using artificial methods and theories. Researchers from different fields work together to explore new concepts, theories, and methodologies in order to create a successful and brilliant future in the modern 21st century.

Aims of Series on Intelligence Science

The Series on Intelligence Science will reflect the most updated progress and achievements in intelligence science, and provide a platform for scientists to exchange new ideas and share knowledge to promote cross-research between brain sciences, cognitive sciences, and artificial sciences.

Areas of particular interest encompass:

- Cognitive neuroscience
- Perception
- Memory
- Linguistic cognition
- Learning
- Thought
- Emotion
- Nature of consciousness
- Mind modeling
- Intelligent systems

Preferred Publisher of Leading Thinkers
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
The basic theory of intelligence science is urgent need to construct. The goals of the conference is to carry out the theory of collective exploration, put up the discipline kernel of intelligence science.
http://www.intsci.ac.cn/icis2018/

The Third International Conference on Intelligence Science (ICIS2018) will be held in Beijing, China, on November 2-5, 2018, focusing on Intelligence Science, Information Science. It is sponsored by Chinese Association for Artificial Intelligence (CAAI), China Chapter of International Society for Information Studies; Organizer is Peking University; and Co-supported by Beijing Association for Science and Technology (BAST), Beijing Association for Artificial Intelligence (BAAI).
Brain Machine Interface

Emitter
- Motor Imagery
- Conscious Motor Imagery
- Wireless EEG

Brain Computer Interface (BCI)
- Motor Imagery
- Conscious Motor Imagery

Emitter: motor imagery (hands = 1, feet = 0)

Receiver
- Conscious perception of light
- Phosphene perception (yes = 1, no = 0)

Computer
- BLUETOOTH EEG data
- BCI processing
- INTERNET CODE: 0010010...

TMS COMPUTER/ROBOT
- Navigation code
- NEURONAVIGATION Coil location/orientation

Robotized TMS
- No phosphene = 0
- Phosphene = 1
- feet = 0

Light perception
- Internet communication

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Brain Machine I³

- Interface
- Interaction
- Integration

Bidirectional Interaction

Decode
Encode
Musk 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.
Brain Implants

➢ 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.
Chinese 973 Program

- 973 Program (The National Basic Research Program) is China's on-going national keystone basic research program.
- Approved by the Chinese government in June 1997 and is organized and implemented by the Ministry of Science and Technology.
- To meet the nation's major strategic needs.
- To create an excellent scientific research environment and to scale the peak of the world's science.
Chinese 973 Program

973 Program emphases:
- Agriculture
- Energy
- Information
- Resource and Environment
- Population and Health
- Materials
- Synthesis and Frontier Science
1. Brain information representation, encode and decode

2. Cognitive computing for brain-machine collaboration

3. Mutual adaptation and motor functional reconstruction

4. Experimental platforms and Application verification
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- Environment Awareness
- Motivation Driven Reasoning
- Joint Intention Based Collaboration
- Conclusions and Future Works
Environment Awareness

Cyborg intelligent systems require bidirectional information perception between rat brain and computer. Awareness is the state or ability to perceive, to feel events, objects or sensory patterns, and cognitive reaction to a condition or event. Awareness has four basic characteristics:

- Awareness is knowledge about the state of a particular environment.
- Environments change over time, so awareness must be kept up to date.
- Agents maintain their awareness by interacting with the environment.
- Awareness establishes usually an event.
Visual Imagery Processing

- Framework

Environment Awareness

The brain machine collaborative awareness model is defined as 2-tuples: \( \{ \text{Element, Relation} \} \), 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?
Basic Relationships

- 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.
CNN Model

- Convolutional Neural Networks (CNN)
  - Biology visual theory
  - Multi-level hierarchy feature representation

- Weaknesses 😞
  - Weak capability to overcome some noise

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Deep Model B

- Generative Stochastic Networks (GSN)
  - Probability model
  - Without explicitly specifying a probabilistic graphical model
  - Learning deep generative model through back-propagation
  - Stronger capability to overcome noise

- Weaknesses 😞
  - Weak capability to extract the multi-level hierarchies of invariant features

CGSM Model

- Convolutional Generative Stochastic Model (CGSM)
  - Multi-level hierarchy feature representation
  - Stronger capability to overcome noise

(a) Framework of CGSM

(b) Computational graph of CGSM
CGSM Model

- Convolutional Generative Stochastic Model (CGSM)

Output $y_i$ in convolutional layer for input feature map $x_i$:

$$y_{i,k} = \sigma(\tilde{x}_i * w_{i,k} + b_{i,k})$$

Reconstruct output of visible layer:

$$x'_i = \sigma(\sum_k y_{i,k} * w'_{i,k} + b'_{i,k})$$
CGSM Model

- Convolutional Generative Stochastic Model (CGSM)
Roadmap Data

Random Noise

No Noise
### No Noise

<table>
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<tr>
<th>Dataset</th>
<th>Awareness Model</th>
<th>Framework</th>
<th>Recognition Rate (%)</th>
<th></th>
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<td>Single</td>
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<th>Sequence</th>
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What is Motivation

Motivation is an internal process that directs and maintains behavior with a certain goal within an individual that account for the direction, level, and persistence of effort.

Direction — an individual’s choice when presented with a number of possible alternatives.
Level — the amount of effort a person puts forth.
Persistence — the length of time a person stays with a given action.
Motivation Theories

Behaviorist Theory
- Motivation is the result of responses to reinforcement.

Cognitive Theory
- Motivation results from individuals attempting to maintain order or balance and an understanding of the world.

Humanist Theory
- Motivation results from individuals attempting to fulfill their full potential as human beings.

--Wiseman & Hunt, 2001
Maslow’s-Hierarchy of needs theory is based on the assumption that people are motivated by a series of five universal needs.
Bach uses Psi theory to define a possible solution for a drive-based, poly-thematic motivational system.
MicroPsi2 Urgency

MicroPsi2 Urgency

Urgency-based MicroPsi2 Decision-Making

Motivation Learning in CAM

1. Observe $O_{S(t)}$ from $S(t)$ using the observation function
2. Subtract $S(t) - S(t')$ using the difference function
3. Compose $E_{S(t)}$ 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 $I_j(t) \in I(t)$)
7. $Attention = \max I_j(t)$
8. Create a Motivation by Attention.
Motivation Rules

- 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; \( \text{Strength}(P|D) \) is a value within interval \([0,1]\).
Motivation Module in CAM

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

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Motivation System in CAM

Environment

Event receiver
Select Motivation
Create event for motivation

Event list

Dispatcher
Select event
Find applicable candidates

Select candidates

Reasoners

Scheduler
Select intention
Ready list
Execute Plan step
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Cognitive Model of Brain Machine Integration

CAM model

ABGP model
Mind Model CAM
ABGP Model
Joint Intention

- 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.
Individual Intentions

- 1984 Bratman, BDI
- 1990 Cohen and Levesque, intention model.
- 1990 Pollack, intention model
- 1988/1989 Werner, intention model,
  \[ R_{rol} = <I_{rol}, S_{rol}, V_{rol}> \]
Joint Intentions

- 1989 Conte, Group Mind
- 1990 Searle, collective intentions
- 1990 Grosz and Sidner, Shared Plan
- 1988 Tuomela and Miller, we-intentions
- 1990 Singh Group Intentions
Joint Intentions

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 in general terms.
GRATE* : A Cooperation Knowledge Level System

Joint Intention

Joint Intention

Joint Intention
Description Logic

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

TBox(Scheme)

Man = Human \sqcap \text{Male}
Happy-father = Human \sqcap \exists \text{Has-child. Female}\sqcap \ldots

Abox(Data)

John: Happy-father
<John, Mary> : Has-child

Reasoning

Interface
Dynamic Description Logic

- 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: $\neg, \land, \to \forall$;
- Action: $A_1, A_2, \ldots$;
- Action construction: ; (composition), $\cup$ (alternation), $\ast$ (repeat), $?$ (test);
- Action variable: $\alpha, \beta, \ldots$;
- Axiom variable: $\phi, \psi, \Box, \ldots$;
- State variable: $u, v, w, \ldots$;
Dynamic Description Logic

Concepts in DDL are defined as the following:

- (1) *Primitive concept P, top \( \top \) and bottom \( \bot \) are concepts.*
- (2) \( \neg C \), \( C \cap D \), \( C \cup D \) are concepts.
- (3) \( \exists R.C \), \( \forall R.C \) are concepts.
Dynamic Description Logic

An action description is the form of

\[ A(x_1, \ldots, x_n) = (P_A, E_A) \]

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.
Bridge rules provide an important mechanism describing semantic mapping and propagating knowledge for distributed dynamic description logics (D3L). The current research focuses on the homogeneous bridge rules which only contain atomic elements.

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

\[
i: \begin{array}{c}
\text{C} \\
\rightarrow
\end{array} j: \begin{array}{c}
\text{E} \\
\text{(into-concept (relation) bridge rule)}
\end{array};
\]

\[
i: \begin{array}{c}
\text{C} \\
\rightarrow
\end{array} j: \begin{array}{c}
\text{E} \\
\text{(onto-concept (relation) bridge rule)}
\end{array};
\]

\[
i: \begin{array}{c}
\alpha \\
\rightarrow
\end{array} j: \begin{array}{c}
\beta \\
\text{(into-action bridge rule)}
\end{array};
\]

\[
i: \begin{array}{c}
\alpha \\
\rightarrow
\end{array} j: \begin{array}{c}
\beta \\
\text{(onto-action bridge rule)}
\end{array}.
\]

Collaborative Decision Making

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

Maze Simulation of Rat Cyborg

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In the automatic navigation of rats, five bipolar stimulating electrodes separately are implanted in medial forebrain bundle (MFB), somatosensory cortices (SI), and periaqueductal gray matter (PAG) of the rat brain. There is also a backpack fixed on the rat to receive the wireless commands.
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Conclusions

- Intelligence Science is the road to human-level artificial intelligence.
- Develop a cognitive model of brain machine integration
- Environment awareness, motivation and joint intention for collaborative decision-making
China Intelligentization


The Development Plan of the Brain Science and Brain-like Intelligence are under working.
A Sketch Map of the New Generation of AI development planning
Brain Science and Brain Inspired Project

Develop brain-machine intelligence technologies

Understand neural basis of cognitive functions

Develop brain research technology platforms

Develop effective approaches in early diagnosis/intervention of brain disorders

“One body two wings (一体两翼)”
Building the core and developing the applications
Thank You

Intelligence Science
http://www.intsci.ac.cn/