Self-reflective Learning

SAINT Workshop on Self-aware and Autonomous Systems
Lynn Library, SUSTech, Shenzhen, May 7-8, 2019

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목차

1. Human-Level AI and ML

Three AI Paradigms

~ 1985 ~

~ 2015 ~

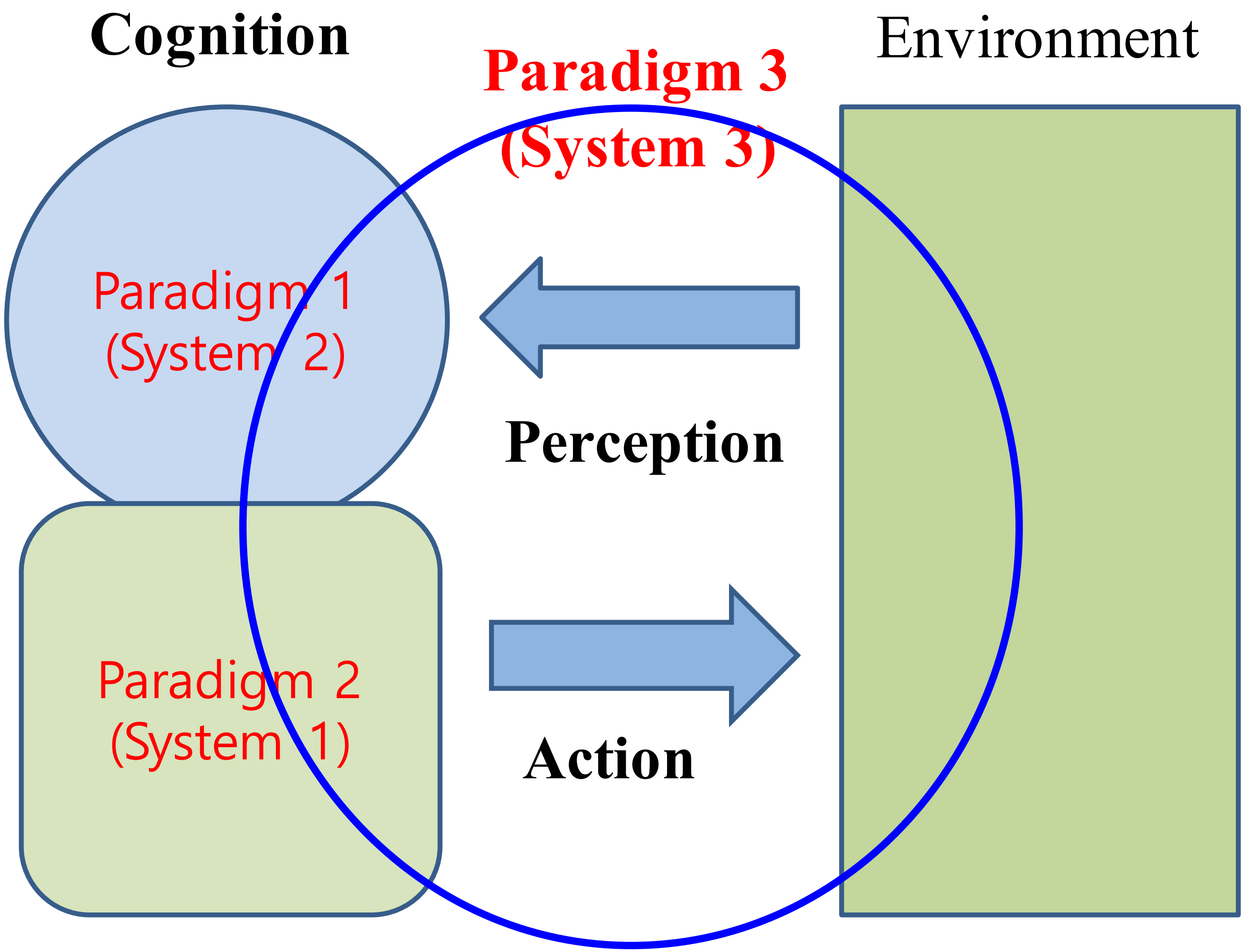
- **Symbolic AI (1G)**
  - Rational/Deductive
  - Logical
  - System 2 (Kahneman)
  - Propositional/Linguistic
  - Thinking/Top-down
  - Knowledge-Based
  - **Reasoning Systems** **(Rules)**

- **Connectionist AI (2G)**
  - Empirical/Inductive
  - Probabilistic
  - System 1 (Kahneman)
  - Iconic/Visual
  - Perception/Bottom-up
  - Data-Driven
  - **Learning Systems** **(Networks)**

- **Cognitive AI (3G)**
  - Constructivistic/Dynamic
  - Temporal
  - System 3
  - Enactive/Grounded
  - Action/Interactive
  - Reward-Based
  - **Cognitive Systems** **(Agents/Robots)**

[Zhang, 2018] Human Intelligence and Machine Intelligence: Cognitive AI, *Communications of KIISE*, 36(1): 27-36, 2018.

New Paradigm: AI as Cognitive Systems



[Zhang, 2008]
[Zhang, 2012 a,b,c]
[Zhang, 2018]

- **Cognition grounded by dynamic perception-action cycle**
- **Knowledge construction by interaction with the world**

Toward Human-Level Artificial Intelligence

3R: Real-Time Learning in Real-World and Real-Life

Dynamic
Non-stationary

Multimodal
Heterogeneous

High-dimensional

Big Data

Hyperscale

Brain-Like Cognitive Computation

Embodied Cognitive Agents

Human-Level Machine Learning

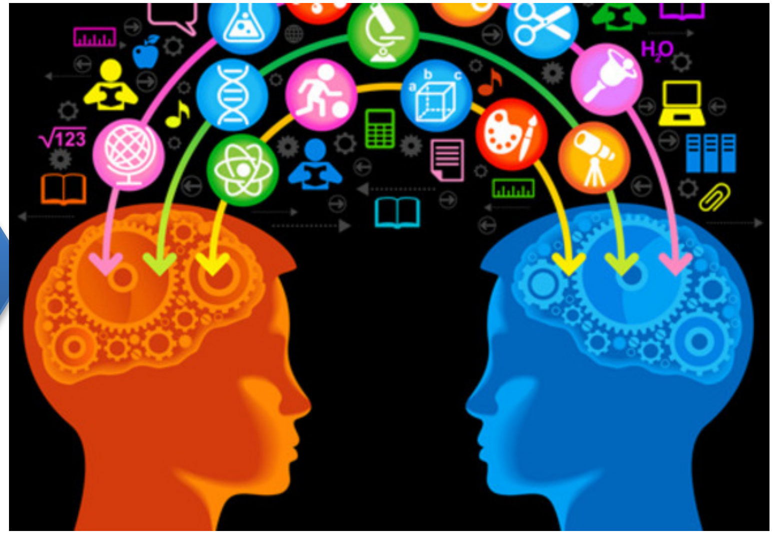
Human-Level Machine Learning

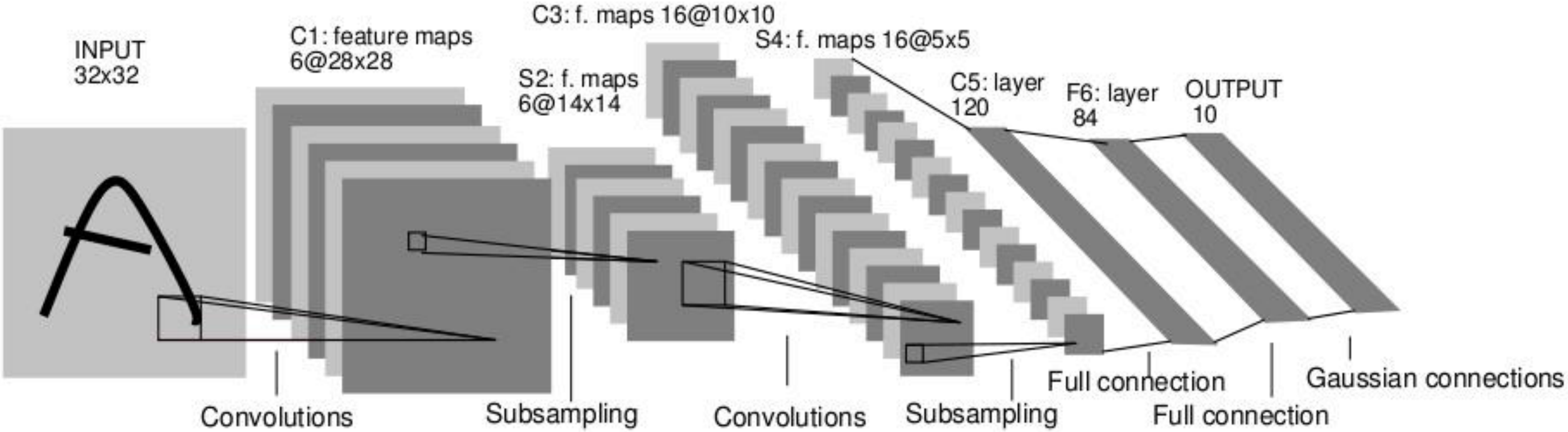
[Zhang, AAAI SSS, 2009]

- Incremental learning
- Online learning
- Fast update
- One-shot learning
- Predictive learning
- Memory capacity
- Selective attention
- Active learning
- Context-awareness
- Lifelong learning
- Persistency
- Concept drift
- Multisensory integration

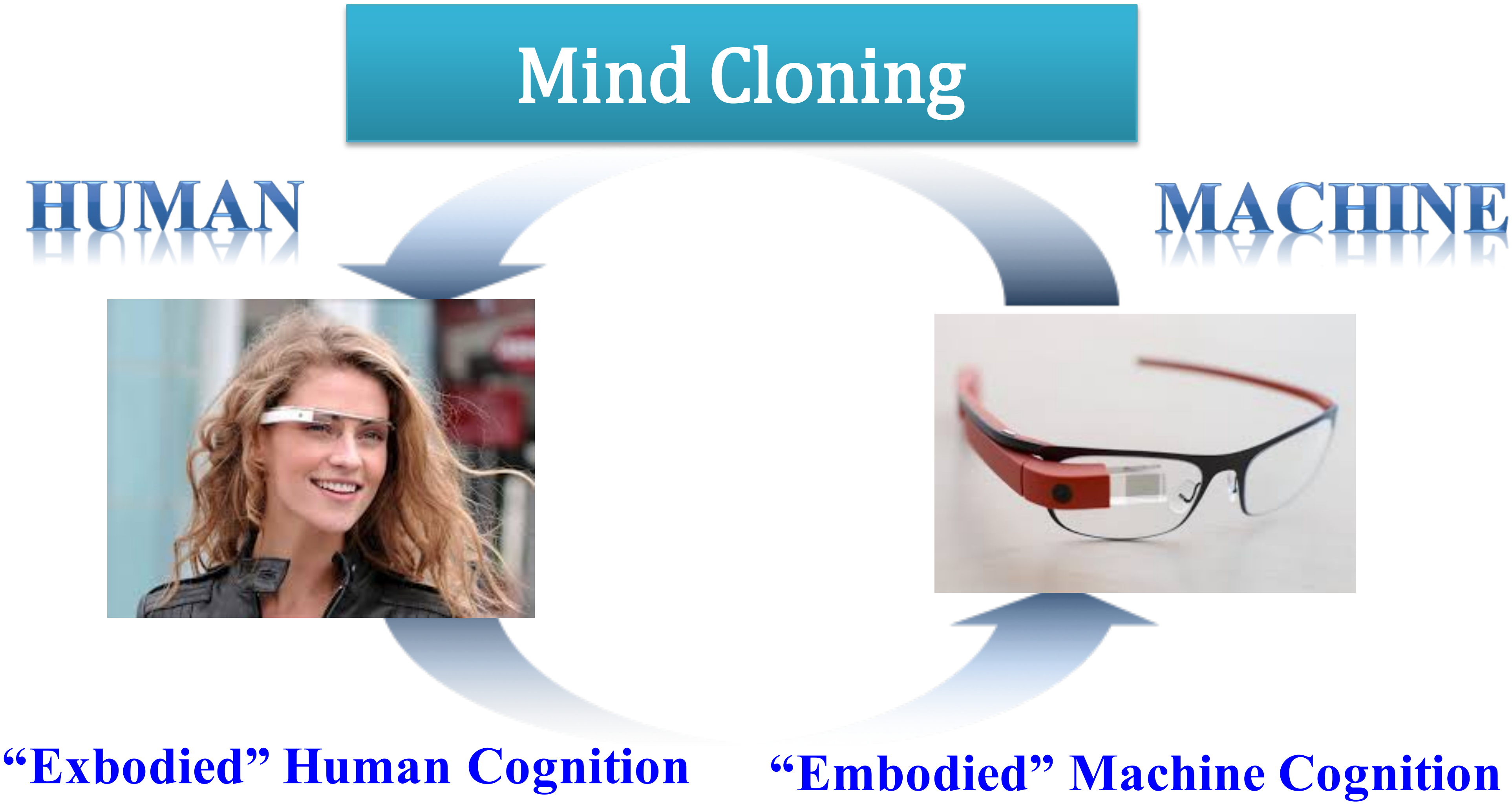
Teaching an agent by playing a multimodal memory game: challenges for machine learners and human teachers, B.-T. Zhang, *AAAI 2009 Spring Symposium: Agents that Learn from Human Teachers*, pp. 144-149, 2009.[PDF]

Mind Cloning: Reverse Engineering the Mind





Mind Cloning



2. Human-Level ML Projects

- Project 1: Wearable Cognitive Agents
- Project 2: Visual Storytelling Agents
- Project 3: Robotic Cognitive Agents

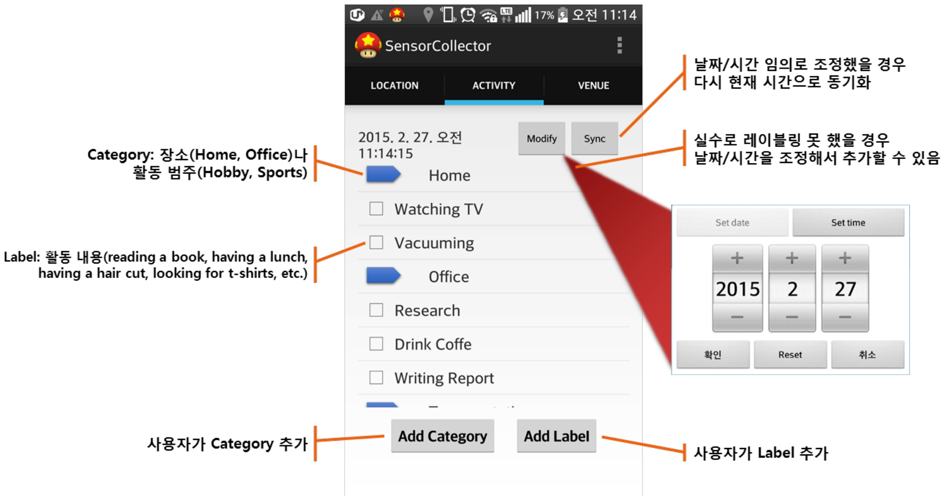
Project 1: Wearable Agents for Everyday Life

- **Real-world lifelogs collected by the Google Glass and Narrative Clip**
  - 84 days (2,000,000 seconds), 3 subjects

[Lee et al., NIPS-2017]

Lifeome - Google Glasses for Lifelong Learning

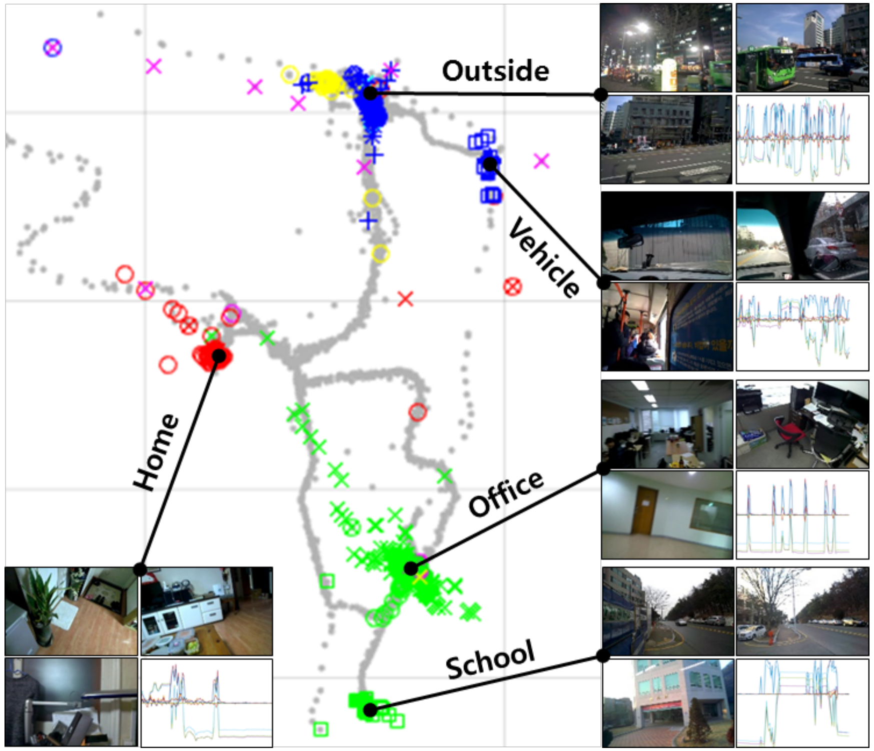
- 3 persons during 14 days for their daily life
- Tools: Google glass, smartphone and a logging application
- Sensors: Camera, MIC, IMU, GPS (A-GPS)
- Logical Information: location (4-Square API), activity (logger app)
- Data size: 537 GB (video) + 2.7 GB (IMU) + 20 MB (GPS) + 70 KB (activity & location

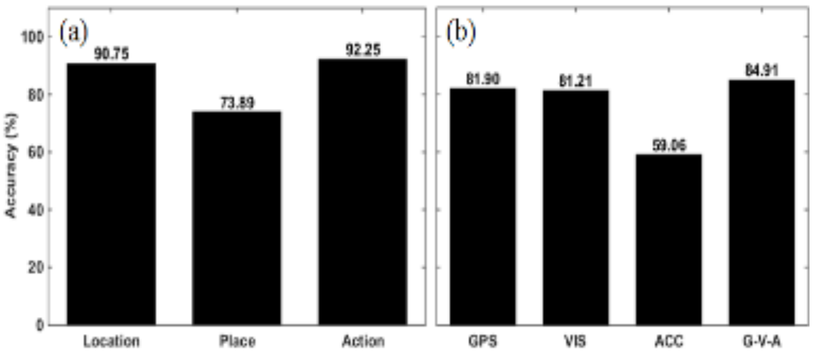


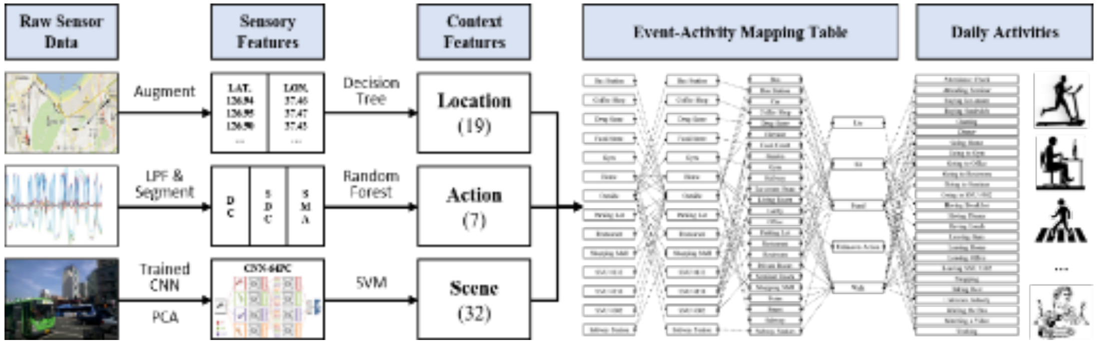
Lifeome - Embodied Cognition of the World

- **Event Recognition**
  (Train instances: 207654, Test: 106974)
  - Location (GPS): 90.75%
  - Place (Vision): 73.89%
  - Action (Accelerometer): 92.25%
- **Activity Recognition**
  (Train instances: 207654, Test: 106974)
  - GPS: 81.90%
  - Vision: 81.21%
  - Accelerometer: 59.06%
  - Integrated Symbolic Events: 84.91%
    (Previous location, current location, place, action)

[Lee et al., Neural Networks, 2017] Lee et al. (2015)





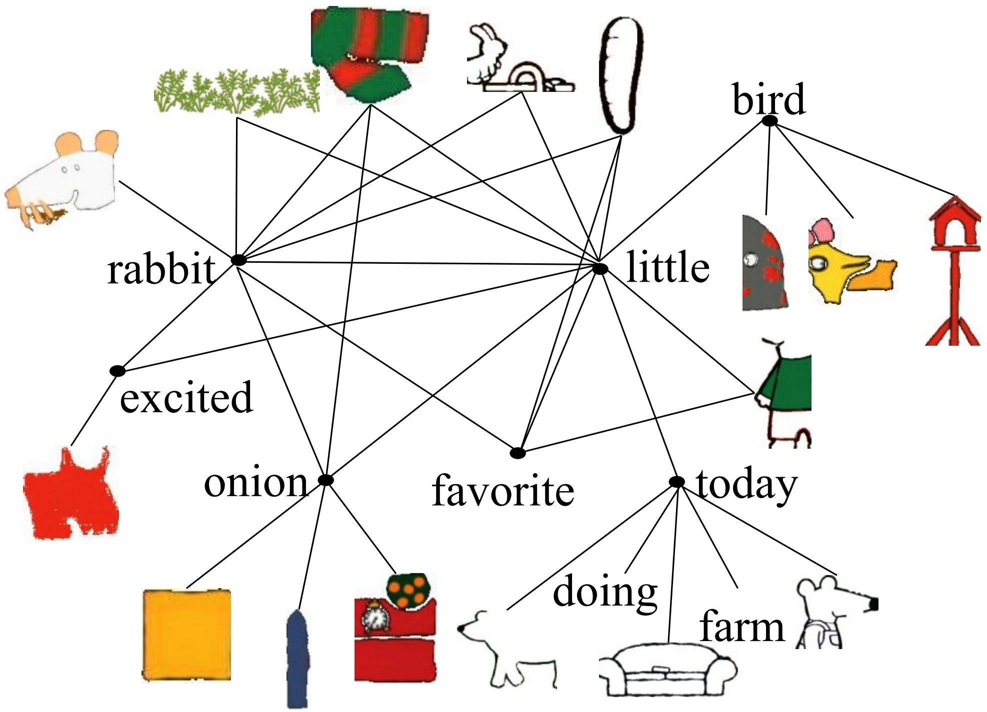


Project 2: Visual Storytelling Agent

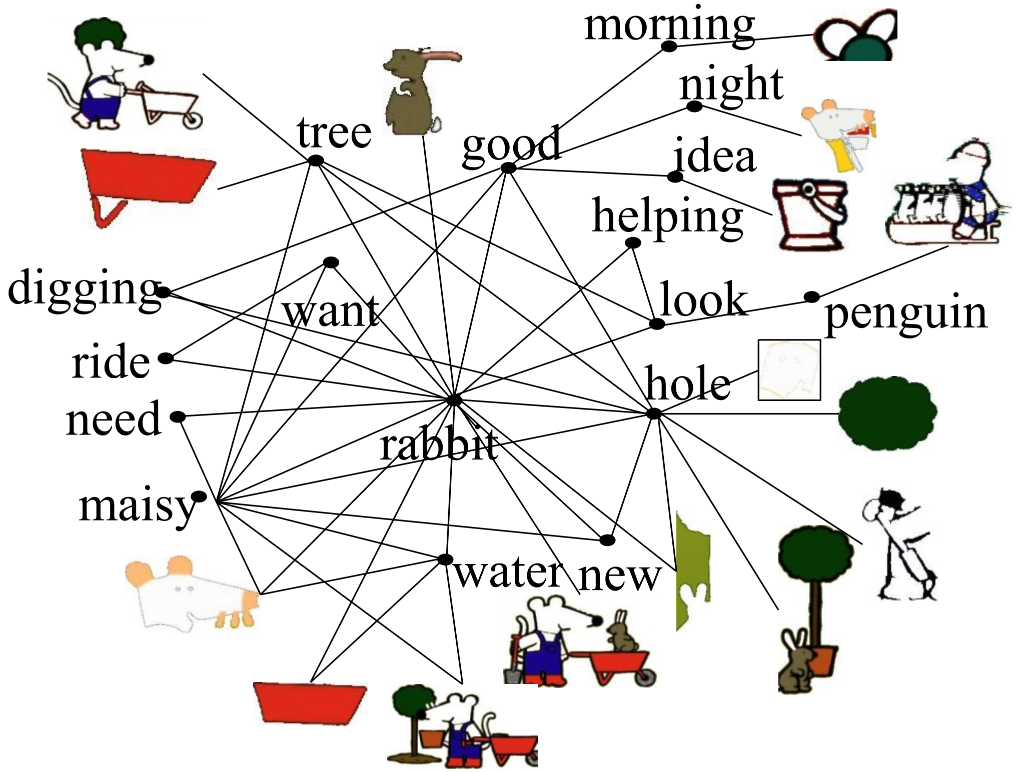
- **Children's cartoon videos**
  - Multimodal
  - Vision + language
  - Simple grammars
  - Explicit story lines
  - Image processing
  - Pseudo-real
  - Educational
  - Cognitive

[Zhang et al., CogSci-2012]
[Ha et al., AAAI-2015]

Constructive Learning by Deep Hypernets



Episodes 1-4



Episodes 1-6

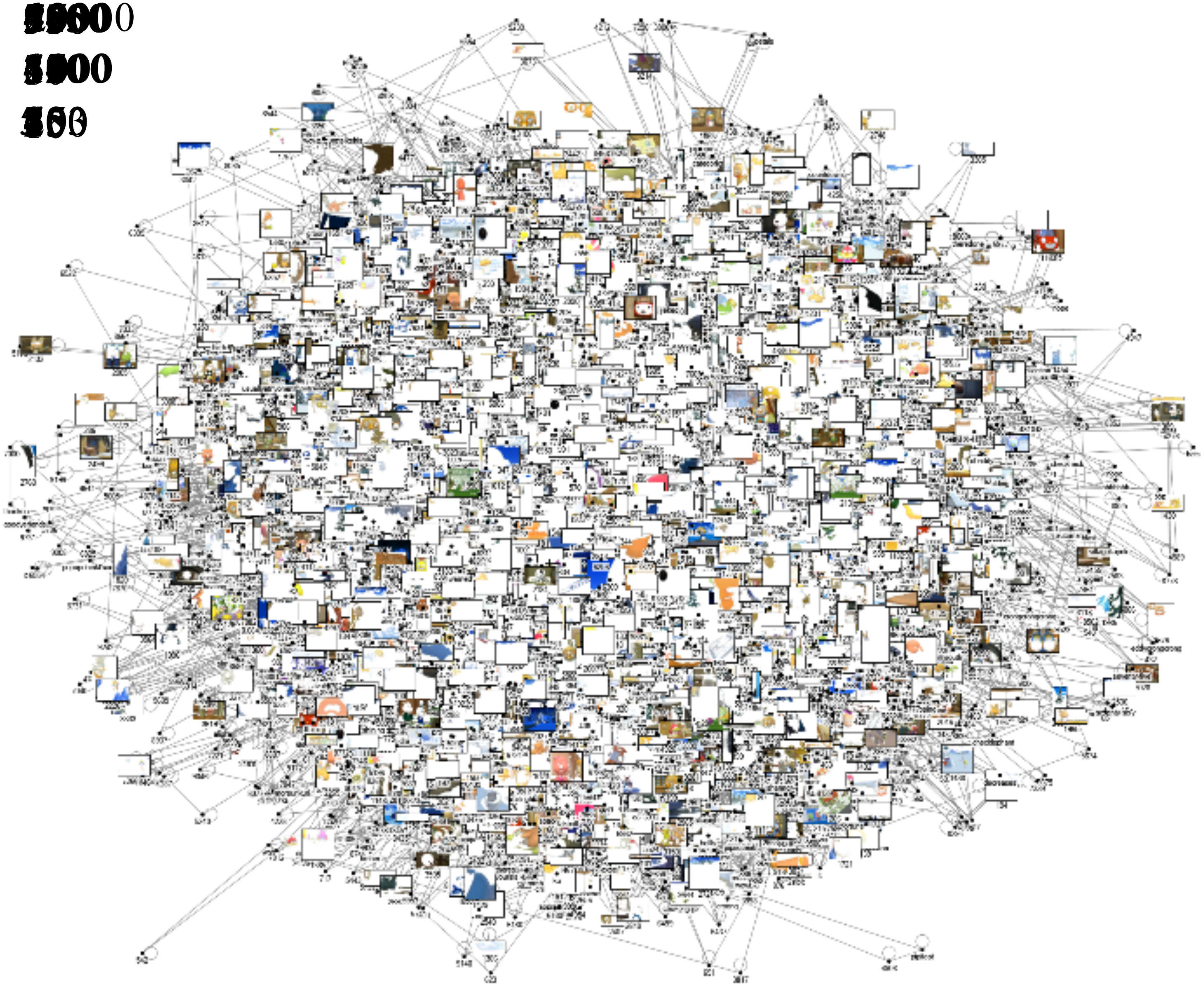
[Zhang et al., CogSci-2012]

Learning from Cartoon Videos

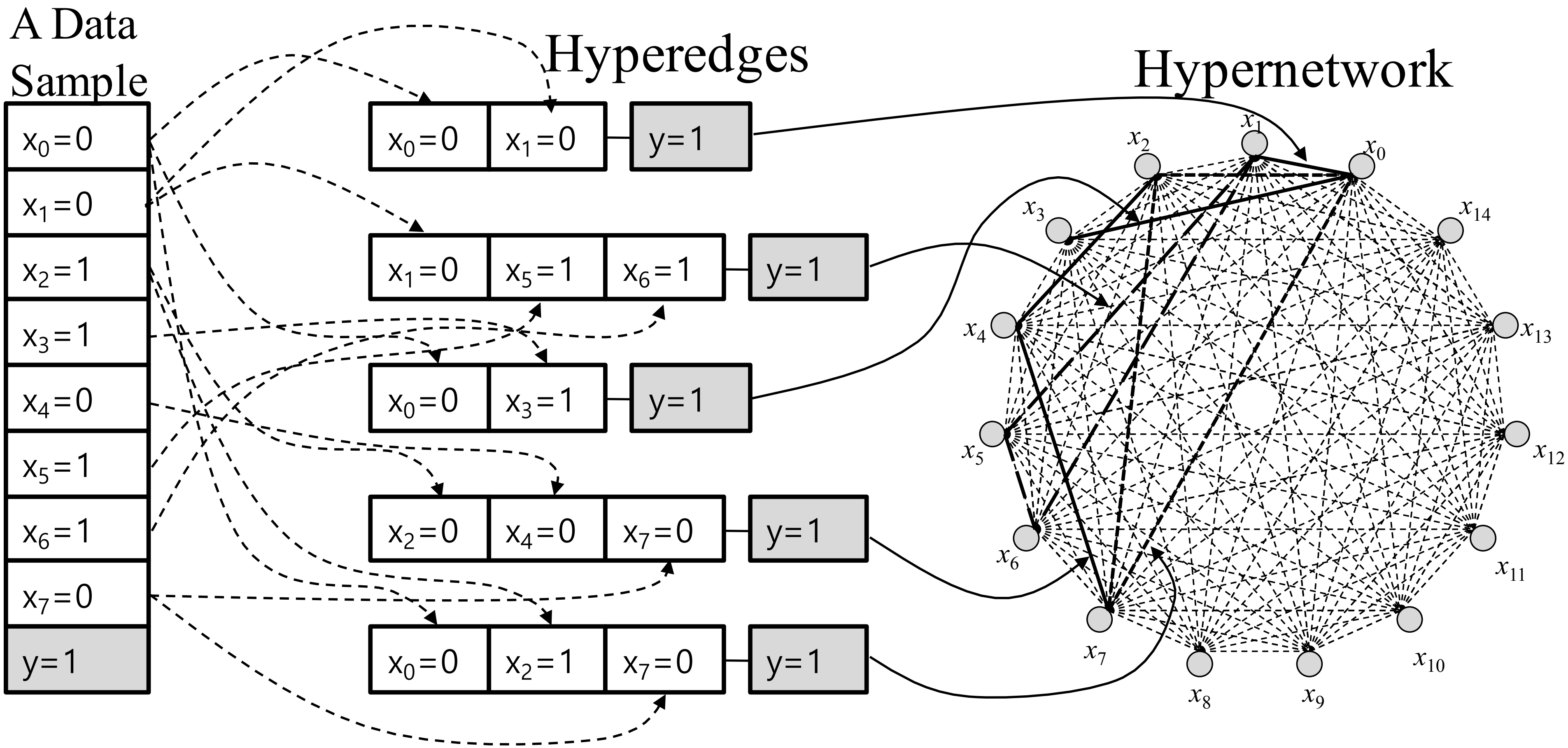
Image 개수 : [illegible]

Word 개수 : [illegible]

Episode 개수 : [illegible]



Evolving Hypernetworks: Hypernet as a Population of Hyperedges



Deep Hypernetworks

- **Deep hypernetworks with hierarchical concept structure are used as knowledge base for Q&A**

Hierarchical formulation

$$P(\mathrm{x}) = \sum_{\mathrm{h}_n} \cdots \sum_{\mathrm{h}_1} P(\mathrm{h}_n \mid \mathrm{h}_{n-1}) \cdots P(\mathrm{h}_2 \mid \mathrm{h}_1) P(\mathrm{h}_1 \mid \mathrm{x}) P(\mathrm{x})$$

Joint probability of hidden variables $\mathbf{h}_i^{(s)}$ in the s^{th} layer

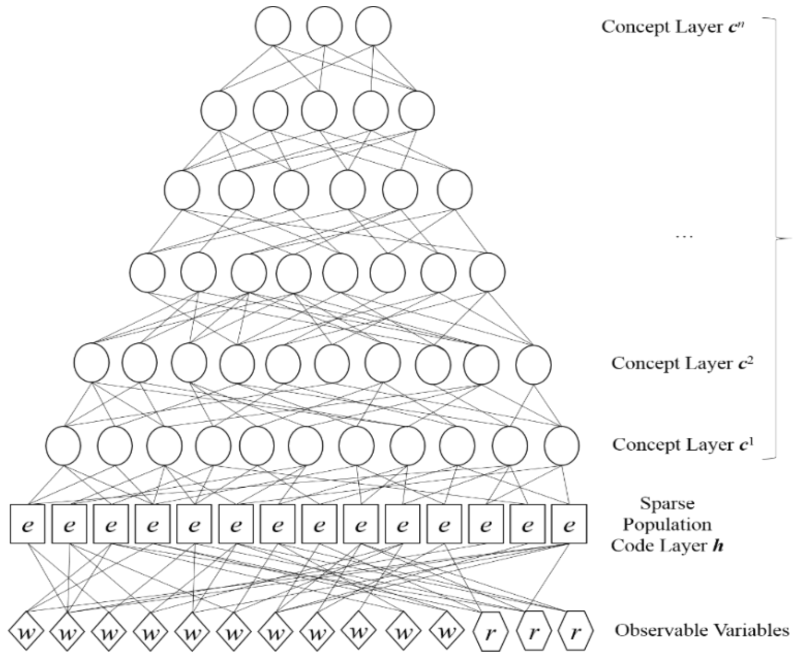
$$P(\mathbf{h}_s) = \frac{\exp(-E(\mathbf{h}_s))}{\sum_j \exp(-E(\mathbf{h}_j))}$$

$$E(\mathbf{h}_j) = h(s(\mathbf{h}_j))$$

$$s(\mathbf{h}_j) = \sum_{i1} w_{i1}^{(j)} h_{i1}^{(j)} + \sum_{i1,i2} w_{i1i2}^{(j)} h_{i1}^{(j)} h_{i2}^{(j)} + \ldots + \sum_{i1,i2,\ldots ik} w_{i1i2}^{(j)} h_{i1}^{(j)} \cdots h_{ik}^{(j)}$$

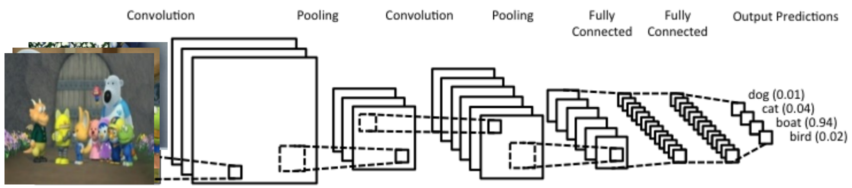
Learning is done by adjusting $s(h_j)$ towards maximizing likelihood $P(x|W)$

$$\frac{\nabla}{\nabla w_{i_1,i_2,\ldots,i_k}^{(k)}} \ln \prod_{n=1}^{N} P(\mathbf{x}^{(n)} \mid W) = N\left\{\left[x_{i_1} x_{i_2} \ldots x_{i_k}\right]_{Data} - \left[x_{i_1} x_{i_2} \ldots x_{i_k}\right]_{P(\mathbf{x}|W)}\right\}$$

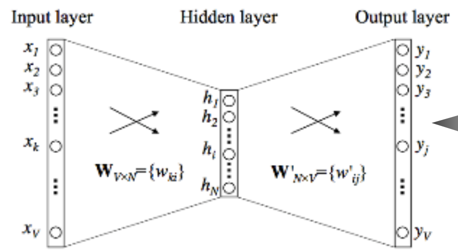


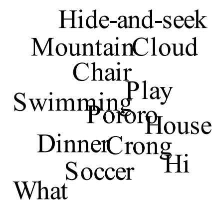
Knowledge Base Construction

Fc7 Feature of Convolutional Neural Networks



Neural Word Embedding Using Word2vec





Preprocessing

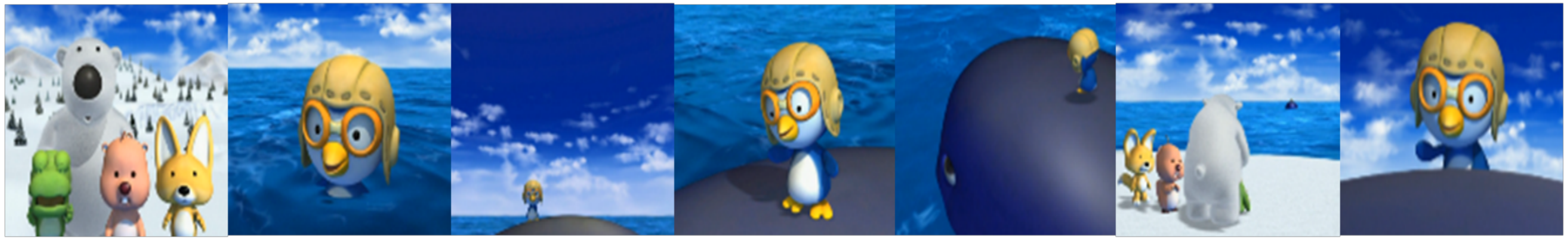
1. K.-M. Kim, C.-J. Nan, J.-W. Ha, Y.-J. Heo, and B.-T. Zhang, "Pororobot: A Deep Learning Robot That Plays Video Q&A Games", *AAAI 2015 Fall Symposium on AI for Human-Robot Interaction* (*AI-HRI 2015*), 2015.
2. J.-W. Ha, K.-M. Kim, B.-T. Zhang, Automated Visual-Lingusitc Knowledge Construction via Concept Learning from Cartoon Videos," In *Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence* (*AAAI 2015*), 2015.
3. B.-T. Zhang, J.-W. Ha, M. Kang, Sparse Population Code Models of Word Learning in Concept Drift, In *Proceedings of Annual Meeting of the Cognitive Science Society* (*Cogsci*), 2012.

Video QA

- **Examples of Video QA using Cartoon Videos 'Pororo'**

* S and L indicate short-term memory and long-term memory

Sequence of Images

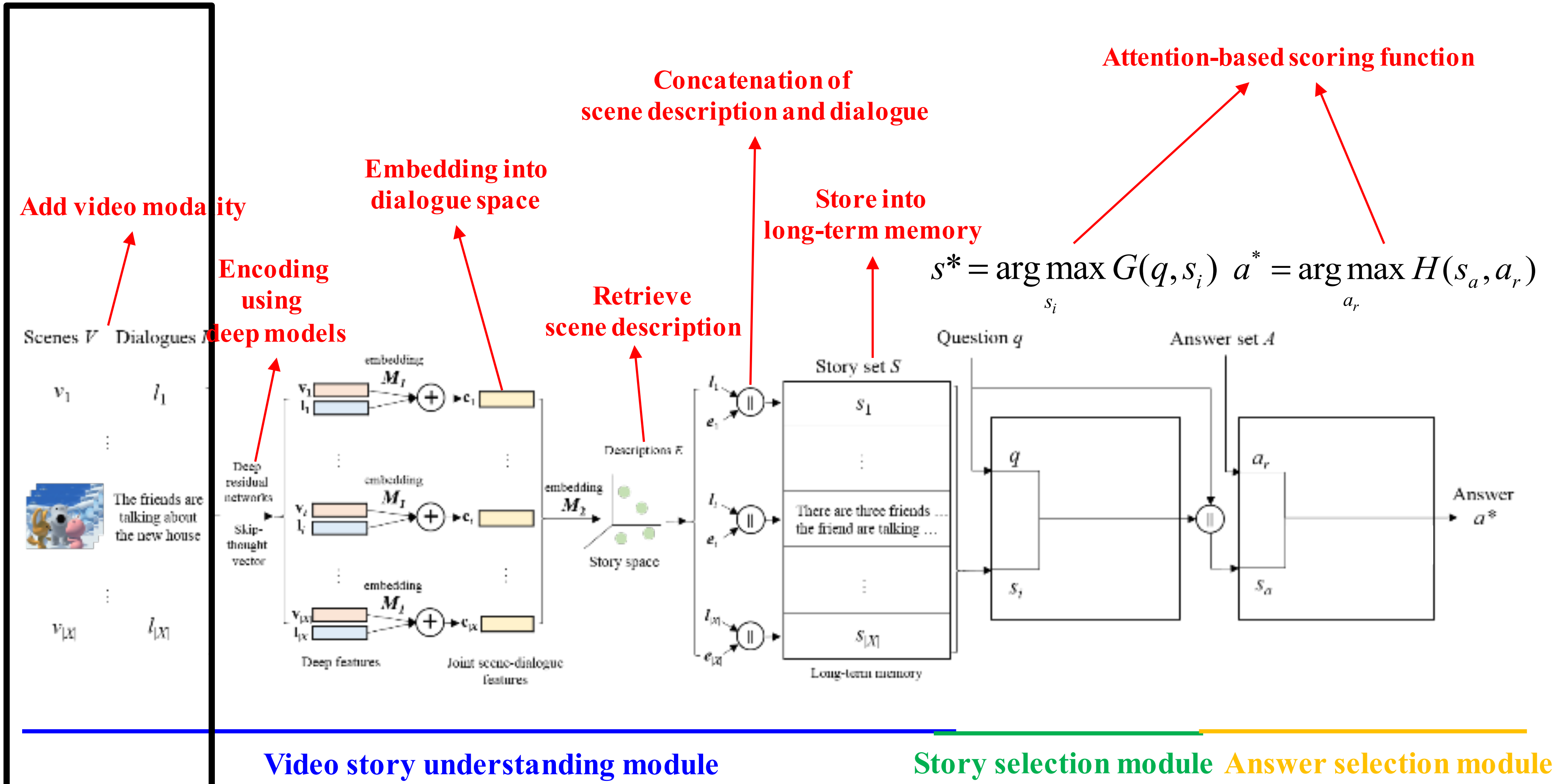


Questions	Answers (S/L)
Can pororo swim out too far?	Yes / Yes
How can pororo swim well?	Because they were so loud / His tall height and great strength

Sequence of Images

Questions	Answers (S/L)
What did eddy trying to go to the playground all day?	Baking / Making a new toy
What does eddy find in her sleep?	Stars / Ball

Deep Embedded Memory Networks (DEMN)



[Kim et al., IJCAI-2017]
[Kim et al., ECCV-2018]

* K.-M. Kim, M.-O. Heo, S.-H. Choi, and B.-T. Zhang, “DeepStory: Video Story QA by Deep Embedded Memory Networks”. *International Joint Conference on Artificial Intelligence* (IJCAI), 2017

VQA in RoboCup@Home (2017)

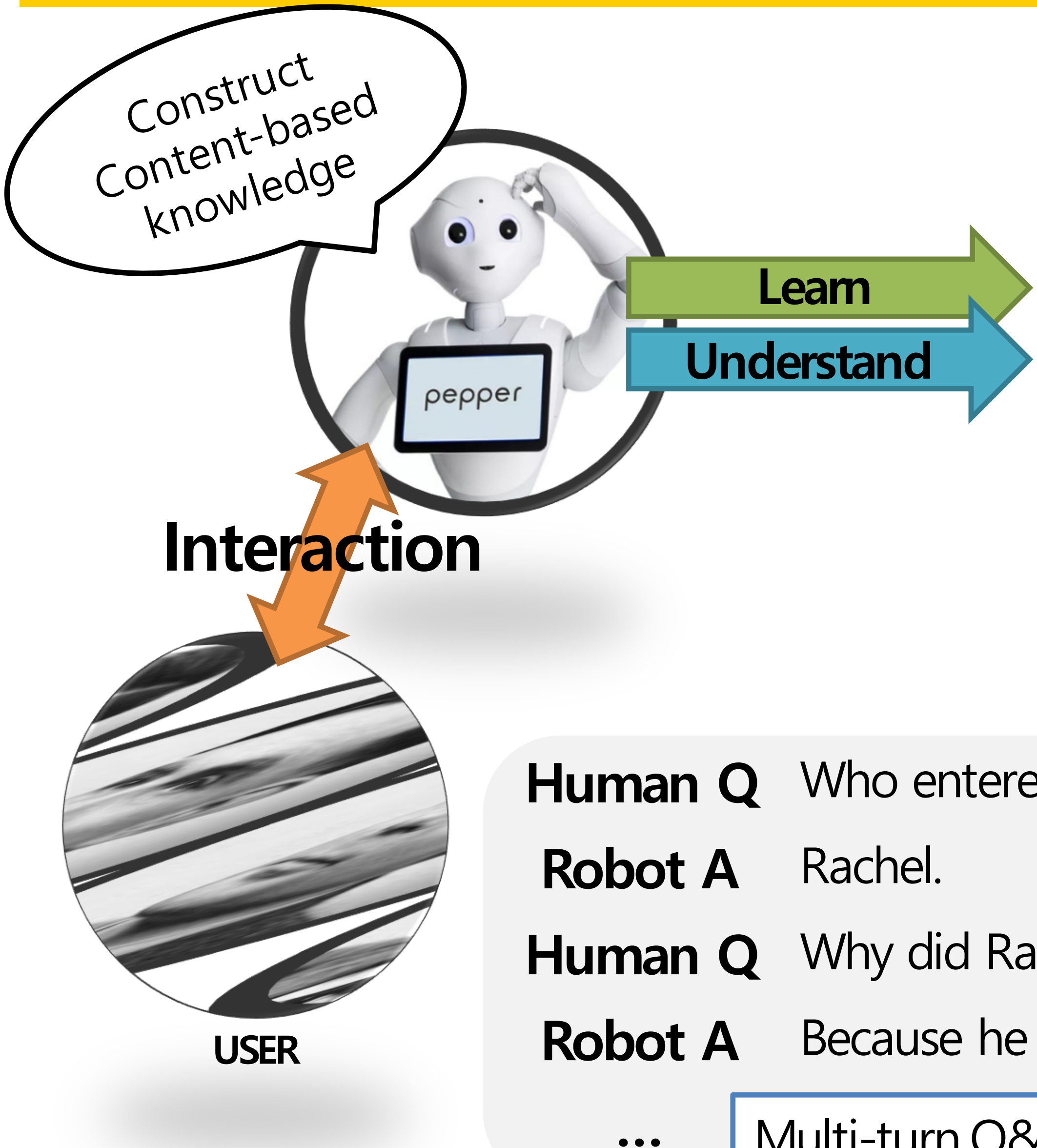
[Ha et al., AAAI-2015]
[KimJ et al., NIPS-2016]
[KimK et al., IJCAI-2017]
[KimJ et al., ICLR-2017]
[Lee et al., NIPS-2018]

Pororobot (SNU)

[Ha et al., AAAI-2015]
[Kim et al., IJCAI-2017]

https://www.youtube.com/watch?v=OtkEkLpjs3s&t=1s

Video Turing Test (VTT): Q&A Dialog on Video Stories



Video as a testbed of real environment

Human Q Who entered the café wearing a bridal dress?

Robot A Rachel.

Human Q Why did Rachel try to leave her fiancé?

Robot A Because he betrayed her.

...

Multi-turn Q&A dialogue about video story

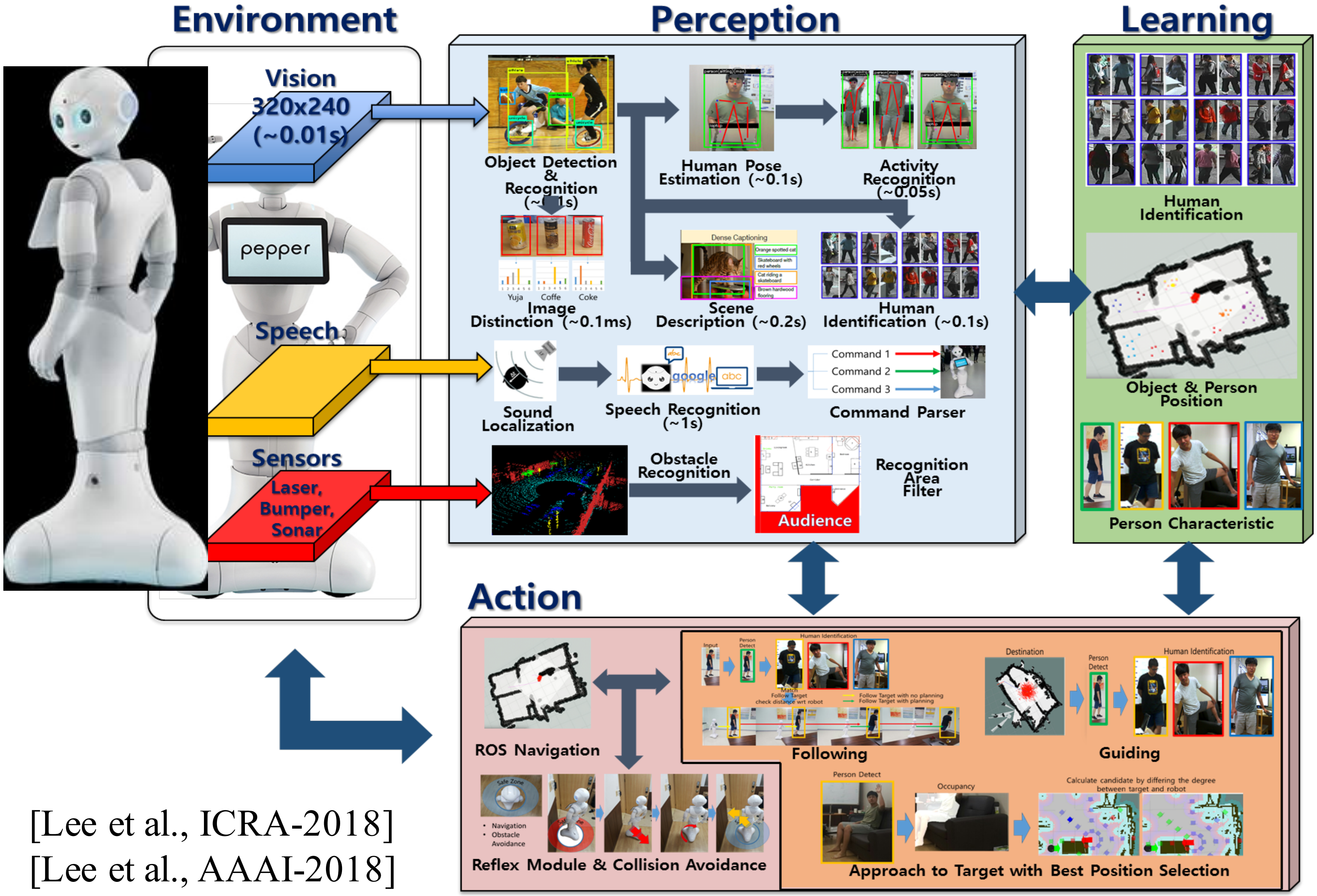
VTT Challenge

Humans and machines watch the same videos and answer the questions.
Audience evaluates who are the humans and who are the machines.

No. 3 is a human!

No. 3 is an AI. No. 5 is a human.

Project 3: Robotic Cognitive Agents for Home Service



[Lee et al., ICRA-2018]
[Lee et al., AAAI-2018]

AUPAIR Robot

AUPAIR Team (SNU & Surromind Robotics)

Winning the ***RoboCup@Home 2017***

https://www.youtube.com/watch?v=a2ZJTpbMWsQ

http://mnews.joins.com/article/21823070#home

Tidyboy: A Home Service Robot (SNU)

https://youtu.be/--TqhXOFun0

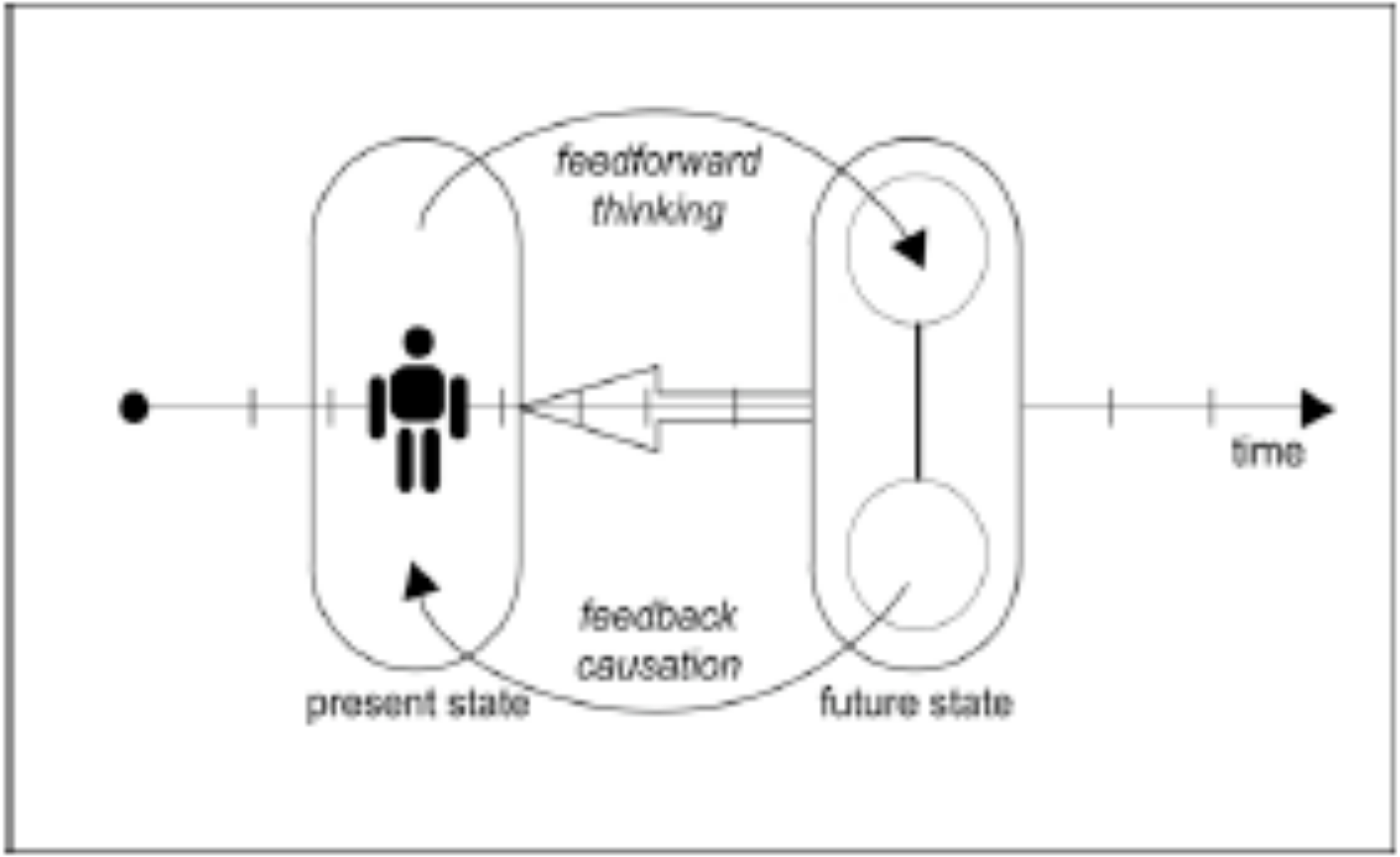
3. Challenge: Self-reflective Learning

Question

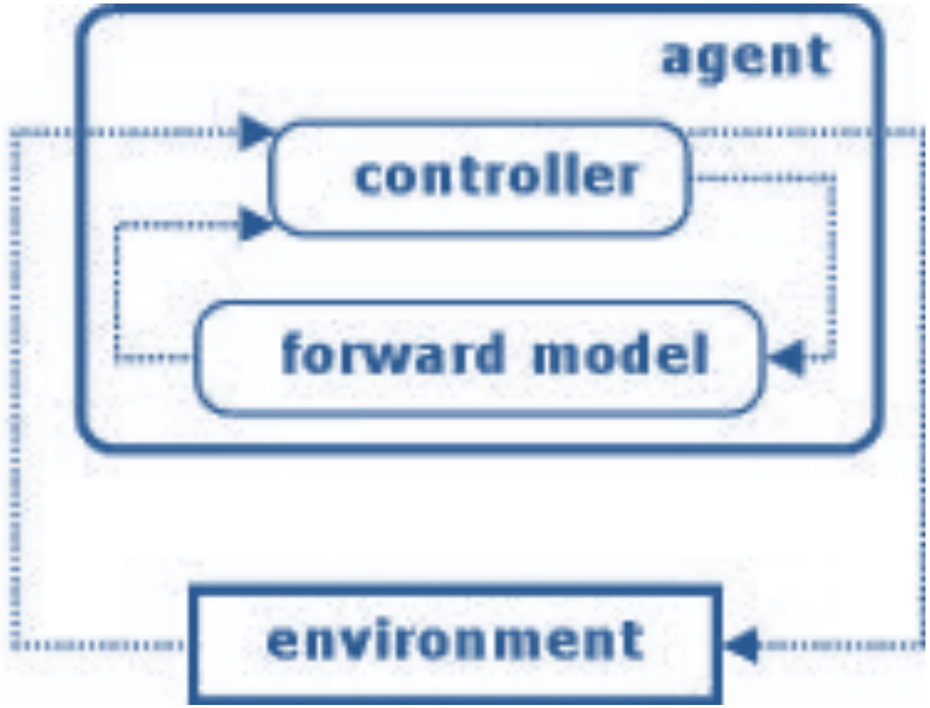
Can machines learn 24/7 continually without human intervention?

Example

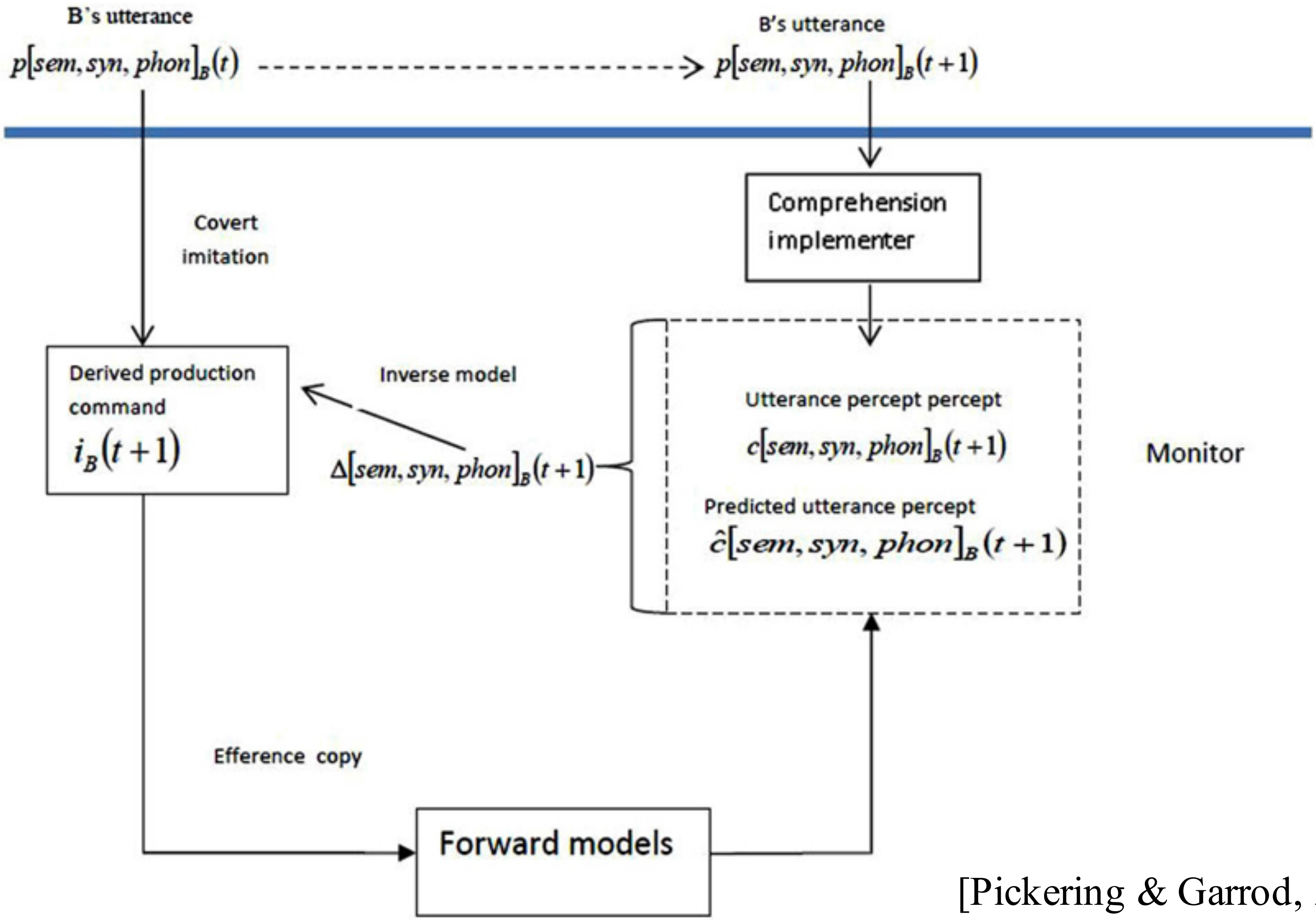
Feedback Causation



Forward Model

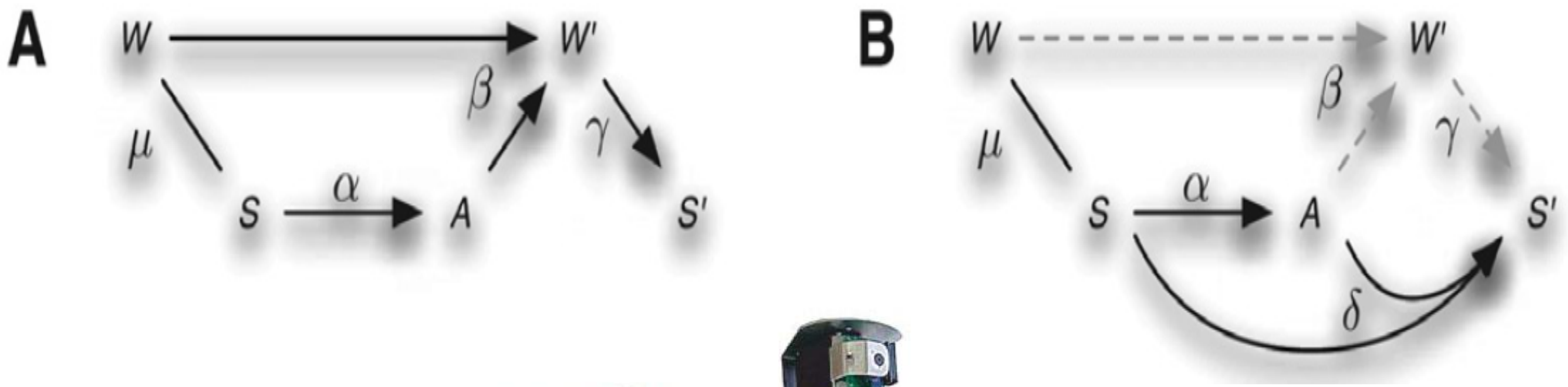


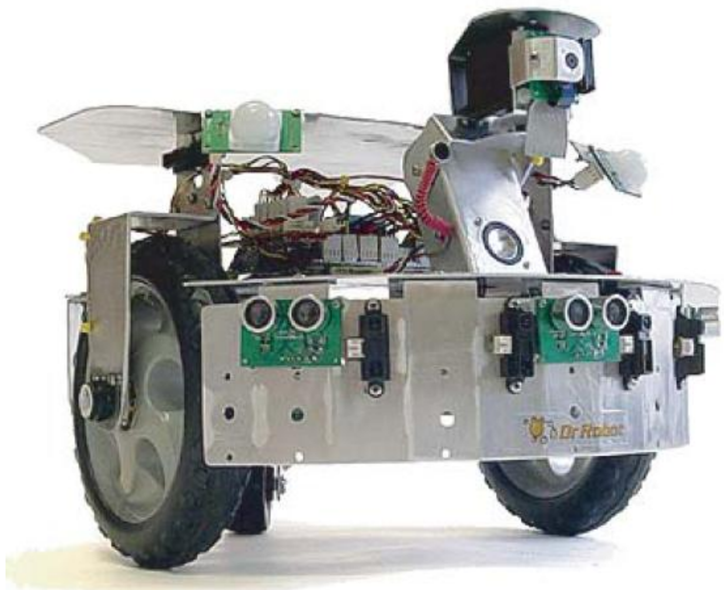
Interactive Alignment Model of Conversation



[Pickering & Garrod, 2013]

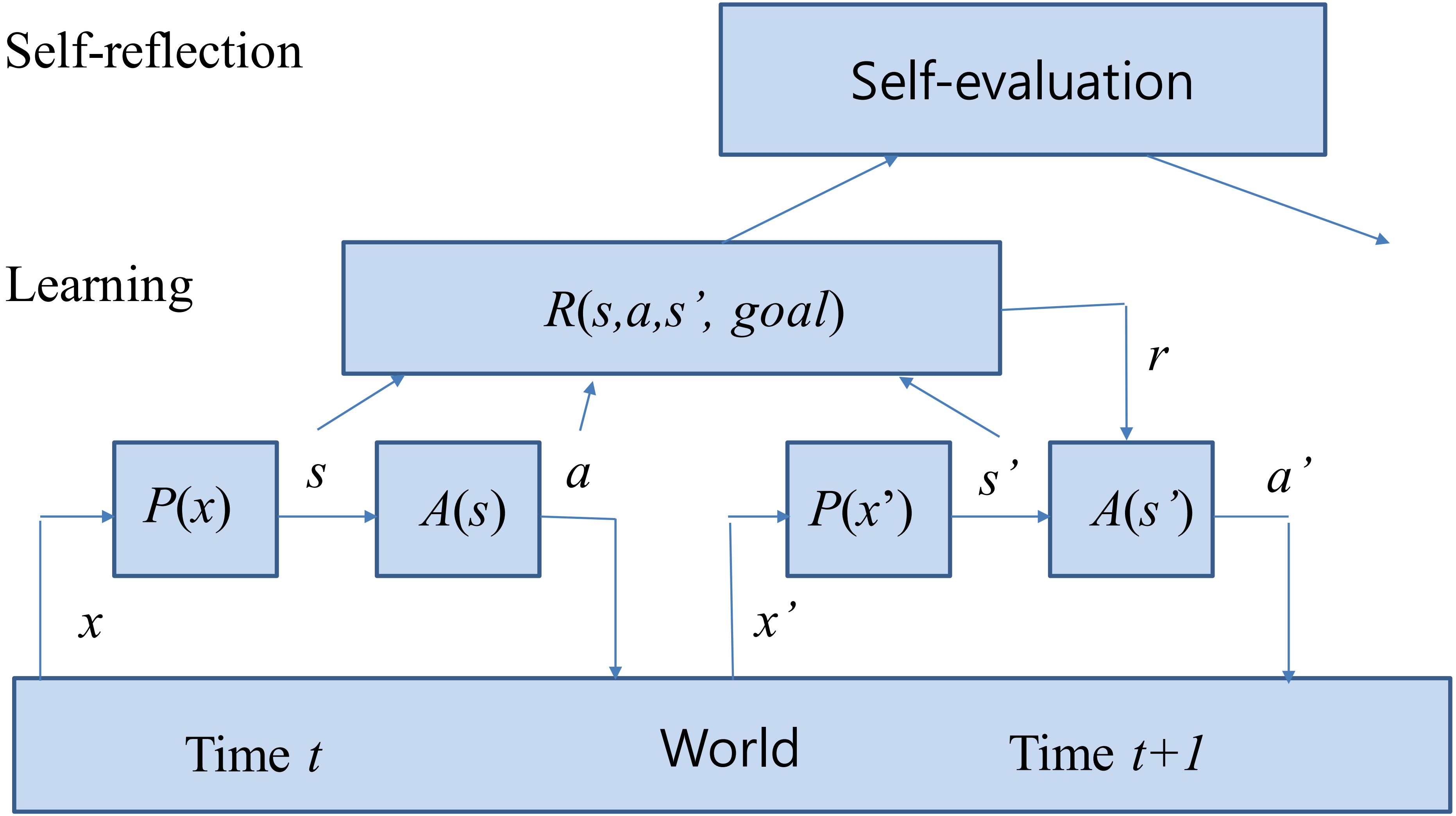
Prediction in the Perception-Action Cycle





[Zahedi *et al.*, *Adaptive Behavior*, 2009]

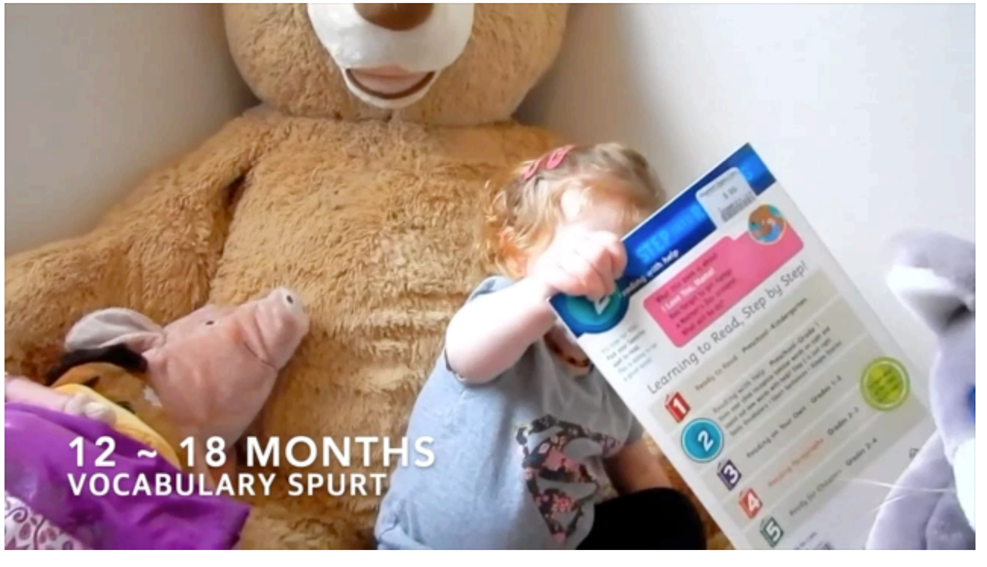
Self-reflective Learning

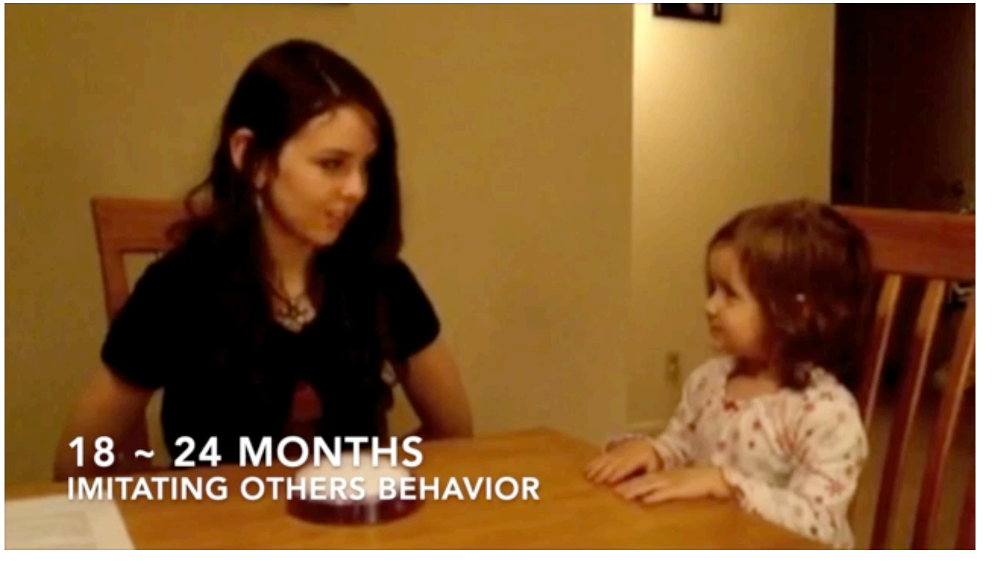


BabyMind


0 ~ 6 MONTHS
PICKING UP SOME OBJECTS


6 ~ 12 MONTHS
RECOGNIZING OBJECT PERMANENCE


12 ~ 18 MONTHS
VOCABULARY SPURT

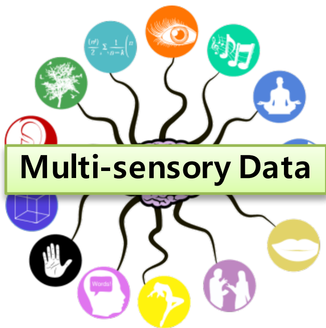

18 ~ 24 MONTHS
IMITATING OTHERS BEHAVIOR

BabyMind

Improving Skills and Knowledge by Continual Learning through Interaction with the Real World

Real-World Data from Real-Life

Active Sensing



Multi-sensory Data

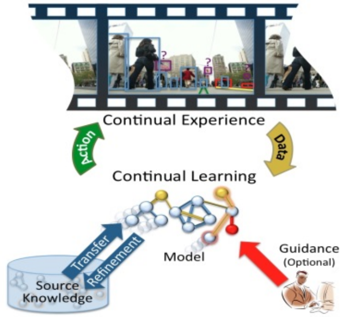
Lifelong Data

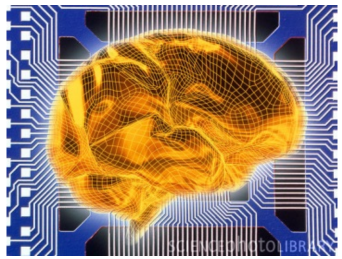
- Heterogeneous
- Continuous
- High dimensional
- Spatiotemporal
- Unlabeled
- Implicit Goal
- Little Big Data

New Paradigm of Machine Learning Inspired by the Brain and Mind

- Self-Supervised Learning
- Episodic/Semantic Memory-based Thinking Process
- Continuous Improvement of Prediction
- Fast/Flexible/Robust Method of Decision Making
- Brain-like Cognitive Architecture

Topology-Preserving Self-organized Map	Hierarchical Modular Cortical Network
Reconfigurable & Self-Organizing	Sparse Population Coding





BabyMind

Traditional AI

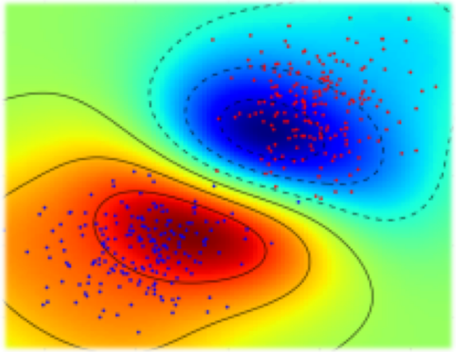
- Passive
- Static
- Closed System
- Supervised Learning
- Deep Networks
- Text-Based Data
- Knowledge-Centric
- Learning from Examples
- Short-term Decision

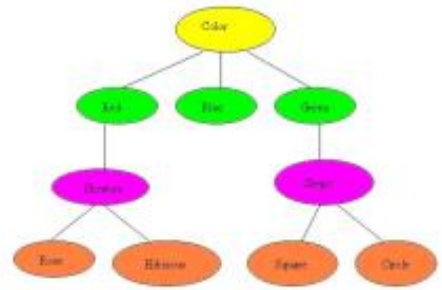
Cognitive AI

- Active
- Dynamic
- Open System
- Autonomous Learning
- Self-developing Networks
- Sensor-Based Data
- Action-Centric
- Learning by Experiment
- Long-term Mission

The Next Generation: Autonomous Learning

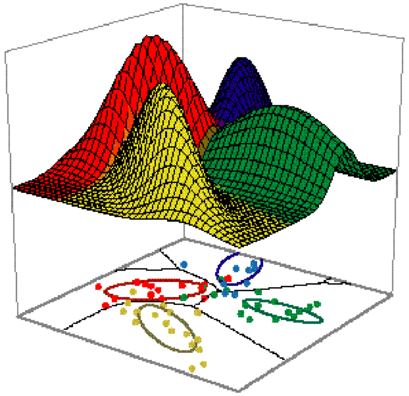
1G: Supervised Learning (1985~2000)





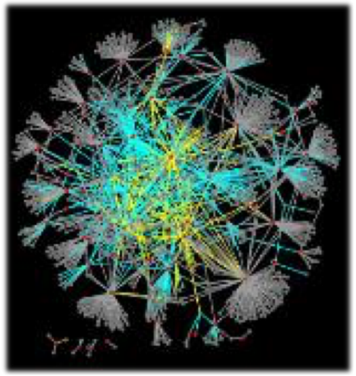
- Decision Trees
- Kernel Methods
- Multilayer Perceptrons

2G: Unsupervised Learning (2000~2015)



- Deep Networks
- Markov Networks
- Bayesian Networks

3G: Autonomous Learning (Next Generation)



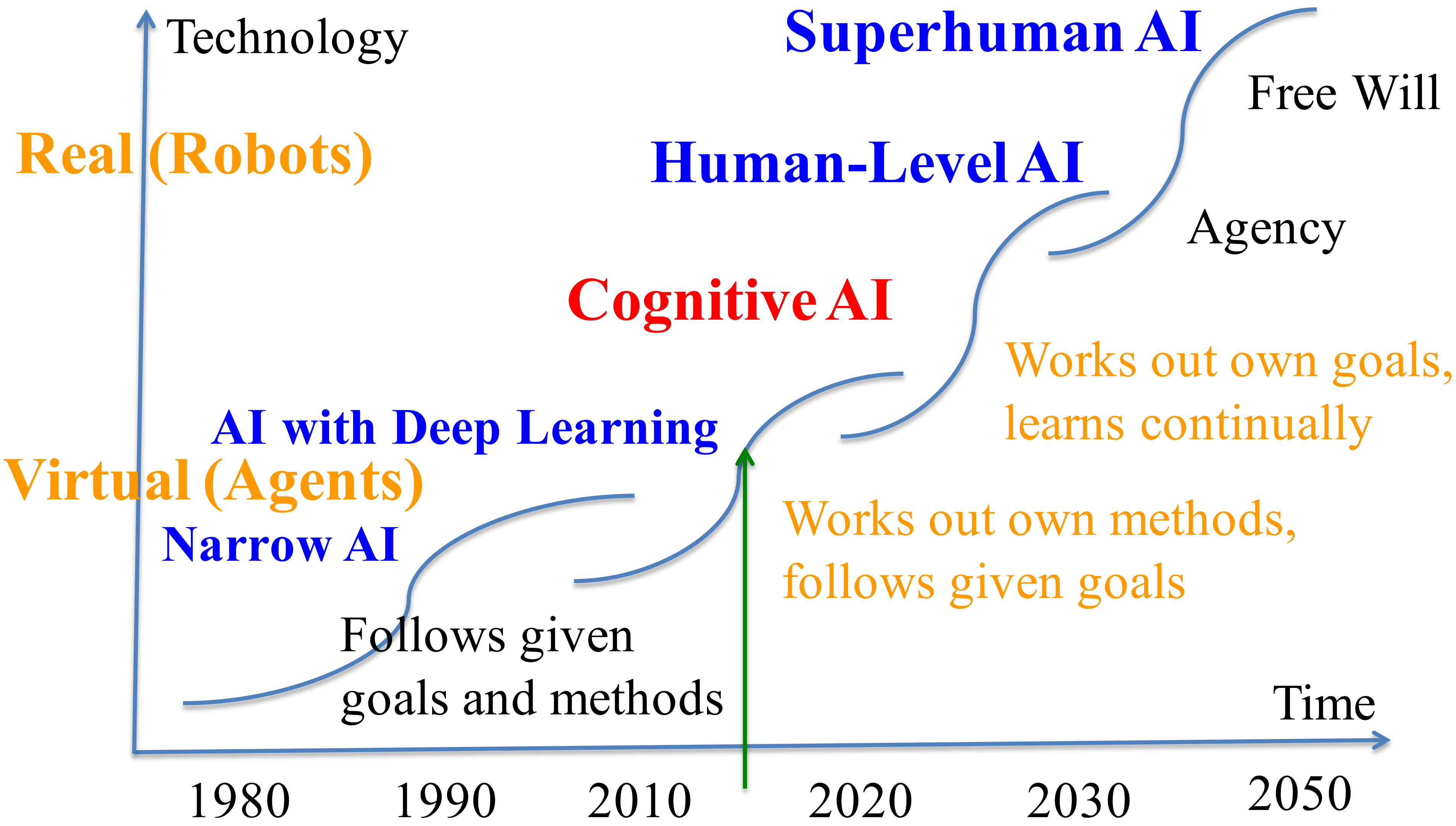
- Learning by Experiment
- Perception-Action Cycle
- Self-reflective Learning

[Zhang, NIPS Workshop 2012; AAAI SSS 2013]

4. Prospect

Autonomous Cognitive Machines

Future of AI



Modified from Eliezer Yudkowsky & David Wood