Symbol Emergence in Robotics and Unsupervised Machine Learning for Language Acquisition

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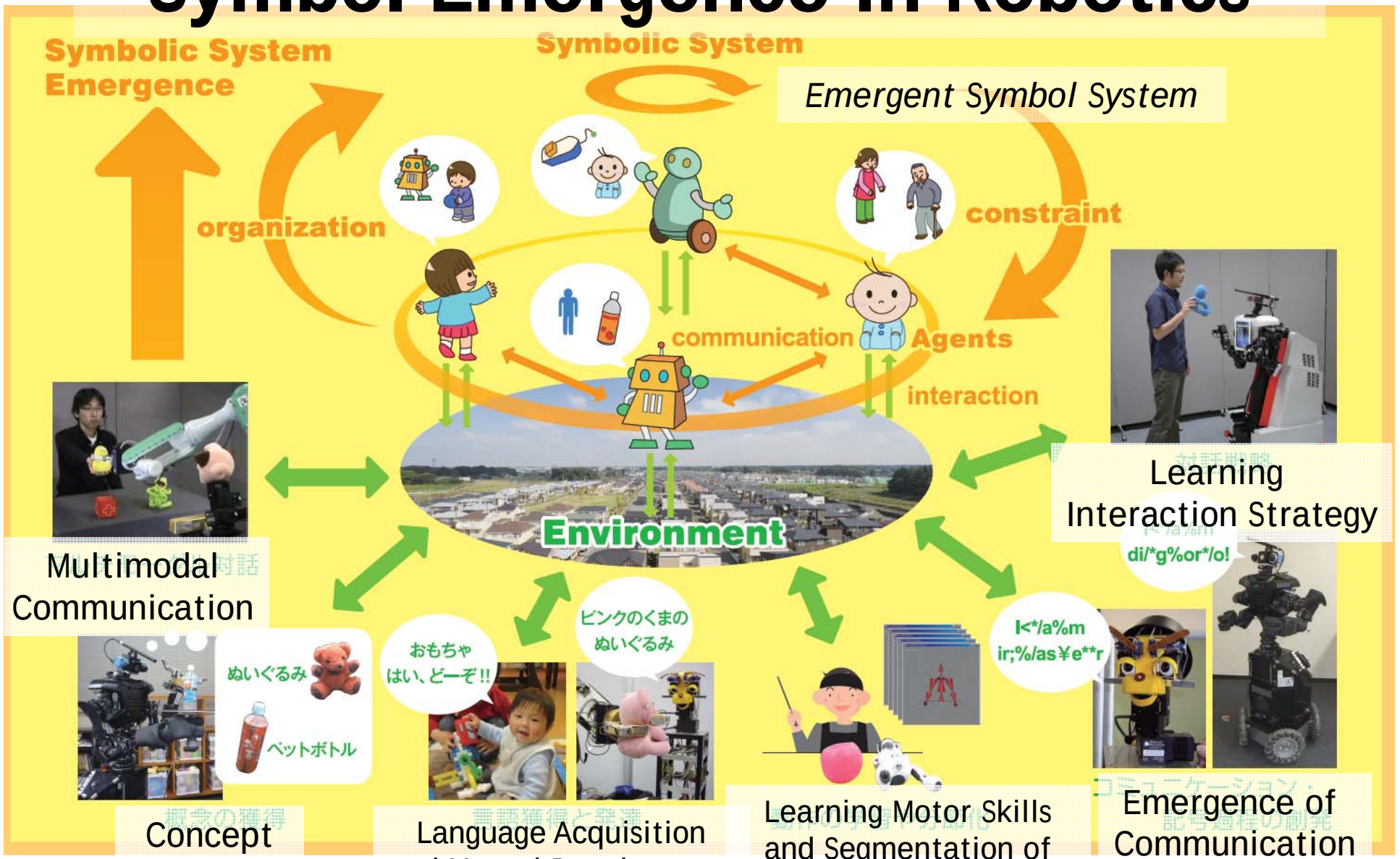
Computational Understanding of Mental Development
From Behavioral Learning to Language Acquisition

- A human child acquires many physical skills, concepts, and knowledge, including language, through physical and social interaction with his/her environment.
- How do we become able to communicate via symbols?
- We'd like to obtain an understanding of the **computational process** of mental development and language acquisition.

Develop robotic and computational models to better understand the original

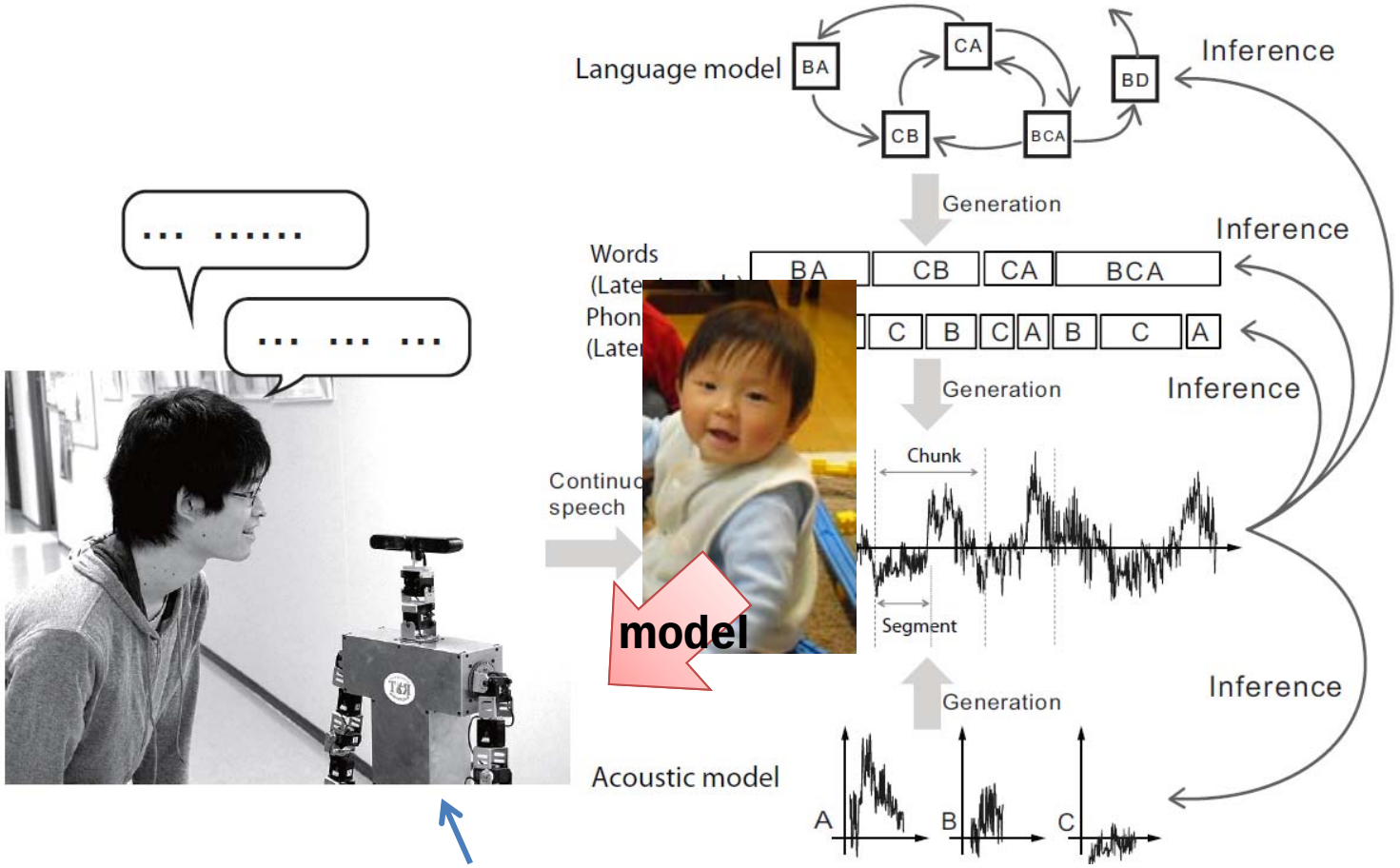
Symbol Emergence in Robotics

Symbol Emergence in Robotics



Tadahiro Taniguchi, Takayuki Nagai, Tomoaki Nakamura, Naoto Iwahashi, Tetsuya Ogata, Hideki Asoh, Symbol Emergence in Robotics: A Survey, (preprint arXiv:1509.08973) (accepted to Advanced Robotics)

Unsupervised Machine Learning for Language Acquisition by a Robot



Without any pre-existing knowledge of **phonemes** and **vocabularies**.

(like human infants)

Unsupervised Machine Learning for Language Acquisition by a Robot

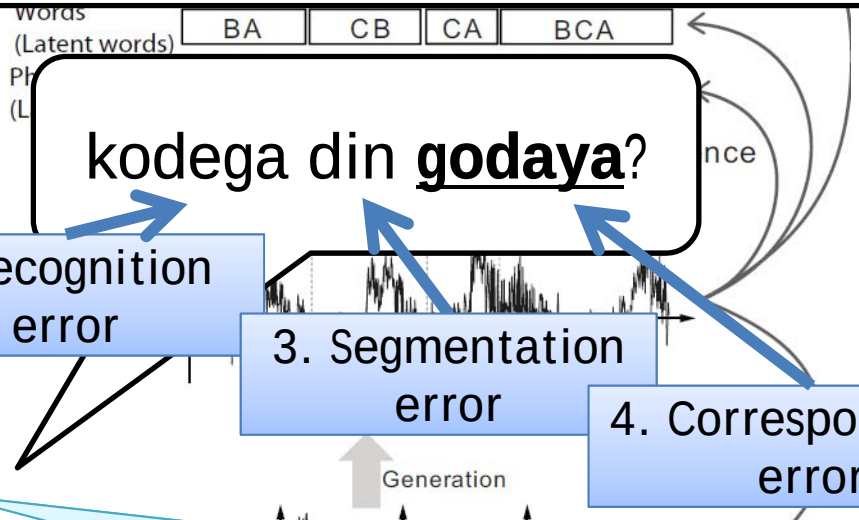
Problems:
How can the robot come to
1. know a set of **phonemes**?
2. achieve accurate **speech recognition** performance?
3. find **word segments** in speech signals?
4. relate words to objects/events?
   (**meanings / correspondence**)

これがりんごだよ！
kore ga **ringo** dayo

… ……

… … …

“Kore Ga **Ringo** Dayo”
= “This is an apple”



kodega din **godaya**?

2.Recognition error

3. Segmentation error

4. Correspondence error

This is a **GODAYA**!!!!

The problems are **mutually dependent**.

1. **NPB-DAA [Taniguchi et al. 2015]**

- How can the robot come to
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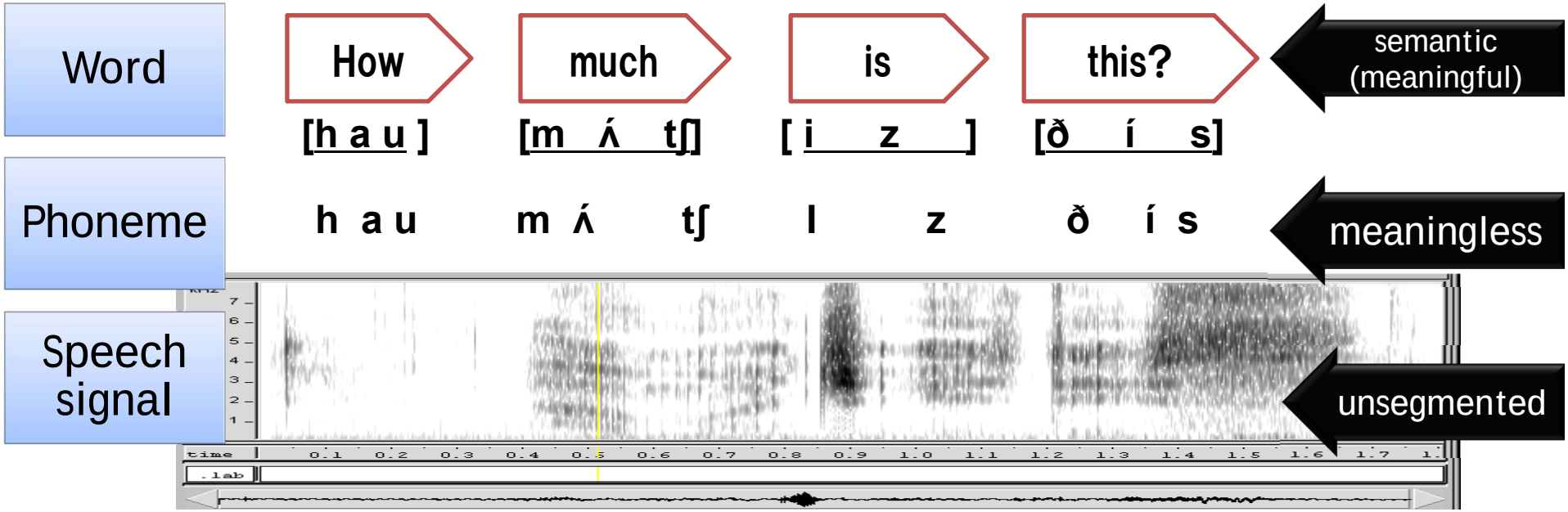
A language learner, i.e., an infant or a robot, has to solve the problems simultaneously.

Double articulation structure in semiotic data

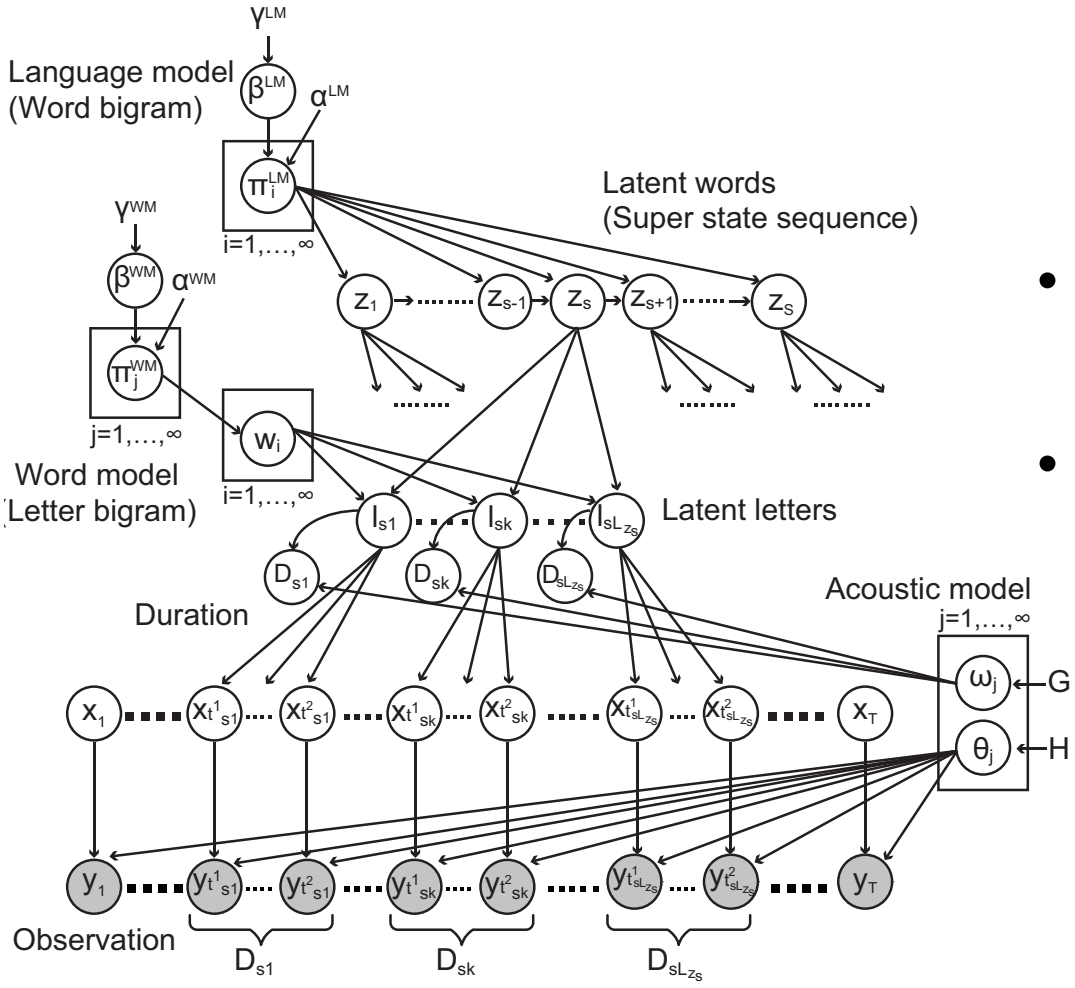
1. NPB-DAA [Taniguchi et al. 2015]

- Semiotic time-series data often has double articulation
  - Speech signal is a continuous and high-dimensional time-series.
  - Spoken sentence is considered as a sequence of **phonemes.**
  - The phonemes are grouped into **words**, and people give them meanings.



1. NPB-DAA [Taniguchi et al. 2015]

Nonparametric Bayesian Double Articulation Analyzer (NPB-DAA) [Taniguchi '15]



- An integrative generative model (HDP-HLM) that combines language and acoustic models simultaneously.
- The model is applied to continuous artificial Japanese vowel speech signals.
- It outperformed baseline speech recognition system-based method.

Method	Letter ARI	Word ARI	AM	LM
NPB-DAA (MAP)	**0.599**	**0.497**		
NPB-DAA	0.574	0.385		
Conventional DAA	0.584	0.072		
Julius (phoneme dictionary + NPYLM)	0.483	0.315	✓	
Julius (phoneme dictionary + latticelm)	0.524	0.426	✓	
Julius (monophone + word dictionary)	0.565	0.548	✓	✓
Julius (triphone + word dictionary)	0.516	0.636	✓	✓

Tadahiro Taniguchi, Ryo Nakashima, Shogo Nagasaka, Nonparametric Bayesian Double Articulation Analyzer for Direct Language Acquisition from Continuous Speech Signals, arXiv:1506.06646

Summary & Open problems

- ✓ **Symbol Emergence in Robotics** is a **constructive approach** towards emergent symbol systems.
- ✓ **Unsupervised machine learning for language acquisition by a robot** is now becoming a (partially) solvable problem recently.
- ✓ **Nonparametric Bayesian approach is** effective for modeling language acquisition process. (Even though deep learning is booming these days.)

Open problems

- ☐ How can a robot learn syntax?
- ☐ How can a robot learn pragmatics?
- ☐ How can a robot understand metaphor?
- ☐ How can a robot use natural language in planning of their behavior?
- ☐ Is human-robot communication and collaboration possible using such a language learned in an unsupervised manner?
- ☐ and so on.

Information

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