Peircean Robotics:
Semiotics applied to the Emergence of Symbols

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- ✔ Please ask your questions **in the chat box on the Webinar system**.
- ✔ You can contact me via email as well after the lecture: kato.takafumi.27z@kyoto-u.jp

Introduction

1. Symbols in Robotics
2. Peircean Semiotics
3. Symbol Emergence Systems
4. Symbol Emergence in Robotics
5. Peircean Philosophy of Mind
6. Symbol Emergence Systems as Future Communities of Inquiry

Conclusion

Introduction

✔How can robots communicate with humans?

- from Robotics, Cognitive Science, Semiotics

✔What exactly is ‘meaning’ for robots and humans; how is this ‘meaning’ generated?

Introduction

（cited from: http://www.em.ci.ritsumei.ac.jp/research/robotics/ ）

- ✔ elucidated system dynamics in which robots equipped with AI and actual bodies find ‘meaning’ through interaction with the environment and other agents
- ✔ This is a constructive approach to ‘Symbol Emergence Systems’
- ✔ based on Charles Sanders Peirce’s concept of ’symbols’

TANIGUCHI Tadahiro

1. Symbols in Robotics

- The traditional concept of symbol (in symbolic AI approach):

> A physical symbol system consists of a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called an expression (or symbol structure). Thus, a symbolic structure is composed of many instances (or tokens) of symbols related in some physical way (such as one token is next to another). At any instant of time, the system contains a collection of these symbol structures. (Newell et al., 1976: 116)

- the 'symbol' system is designed by external designers (researchers and developers). The arbitrariness or autonomy of the symbols was not taken into account.

- Newell, Allen; Alexander Simon, Herbert (1976). "Computer science as empirical inquiry: Symbols and search". *Communications of the ACM* 19, 3, pp. 113-126.

1. Symbols in Robotics

In contrast...

- Brooks (1991a; 1991b) seems to suggest a way forward for robotics with the idea of designing the process by which a robot with a body is able to behave appropriately in its environment.

The fundamental problem:

the confusion between the two notions about ‘symbol’

(A) ‘symbols’ in symbolic AI, i.e. symbols in symbolic logic

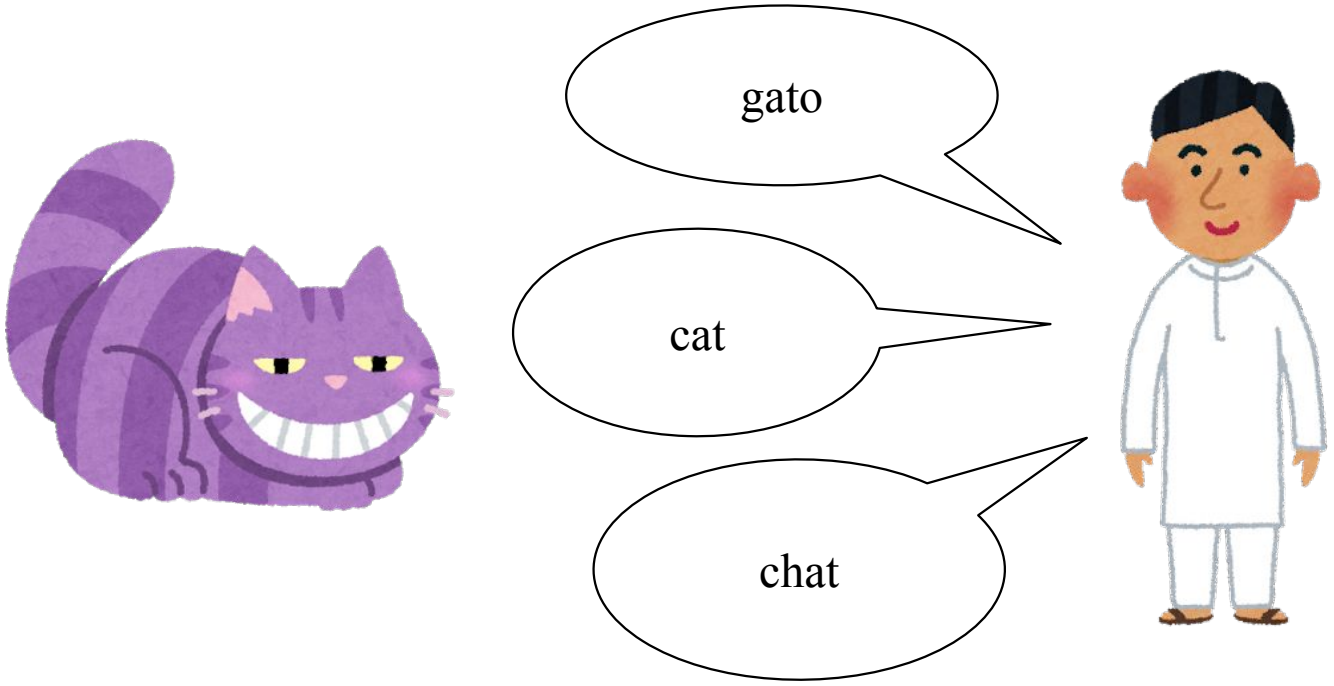
(B) symbols in human society, i.e. symbols as in Peircean semiotics

✔ Even if we could realise a robot that can manipulate such ‘symbols’ as symbolic AI assumes, robots capable of communicating with us in a genuine sense will not be realised.

- Brooks, Rodney (1991a). “Elephants don’t play chess”. *Robotics and Autonomous Systems* 6, pp. 3-15.
- Brooks, Rodney (1991b). “Intelligence without representation”. *Artificial Intelligence* 47, 1-3, pp. 139-159.

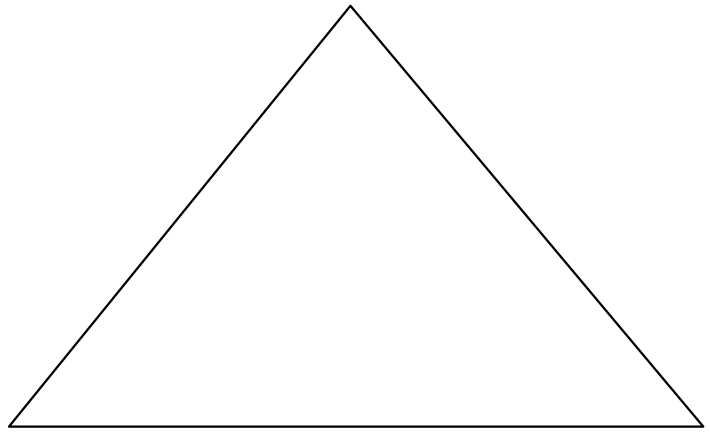
2. Peircean Semiotics

- Semiology
  - ✔ From Ferdinand de Saussure (1857-1913)
  - ✔ Dyadic relation between signifiant (signifier) and signifié (signified)
  - ✔ Arbitrariness of signs



2. Peircean Semiotics

- Semiotics
  - ✔ From C. S. Peirce (1839-1914)
  - ✔ Triadic relation consisting of the sign, the object, and the interpretant
  - ✔ Plasticity of the sign's meaning



2. Peircean Semiotics

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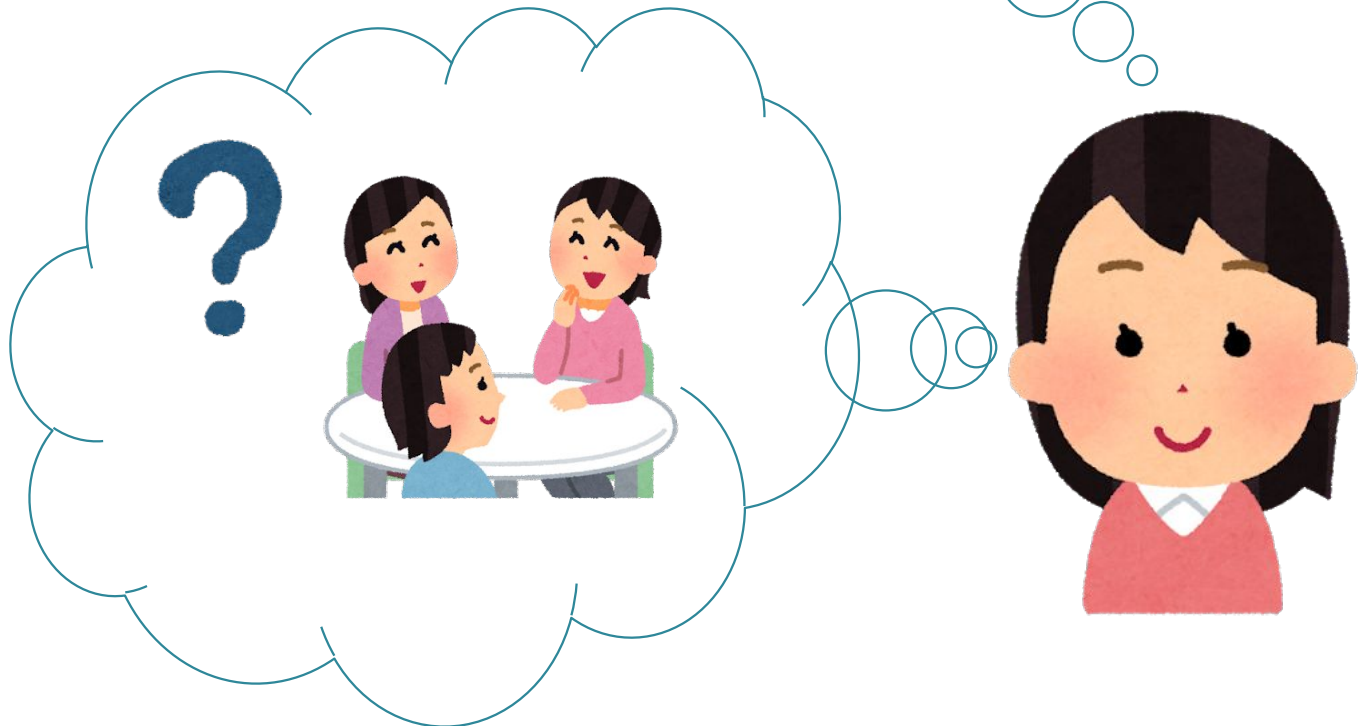
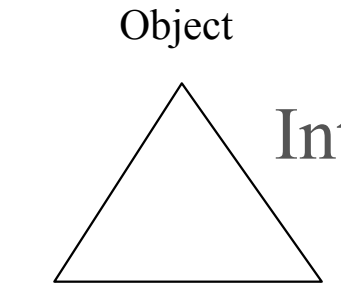


2. Peircean Semiotics

- ✔ Semiosis (Sign process)
  - we can focus on:
    - how the interpretant is formed,
    - how the triadic sign process is established and changes (or evolves)

- ✔ Icon, index, symbol and a collective semiosis

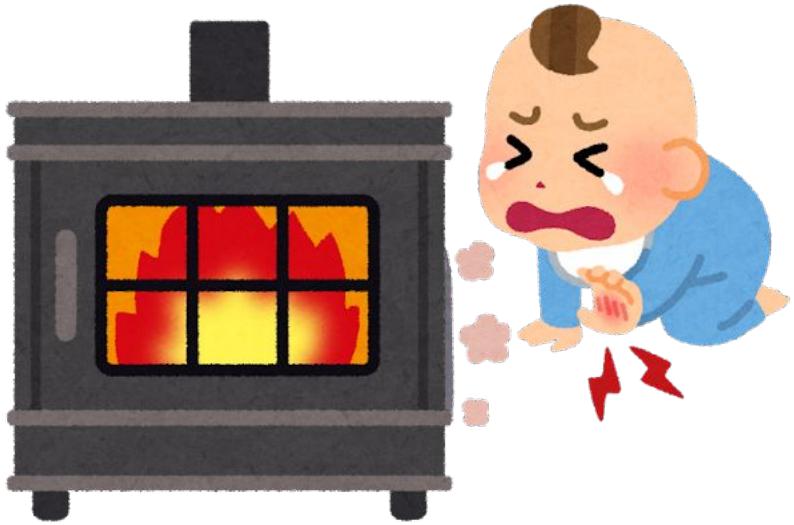


Interpretant
=habits and conventions in a human mind

SEMIOSIS

2. Peircean Semiotics

- ✔ How is the collective semiosis of the human mind established?
  - “Questions Concerning Certain Faculties Claimed for Man” (Peirce, 1992 [1868]: 11-27)



- ✔ The child “suppose a self in which this ignorance can inhere” (Peirce, 1992 [1868]: 20)

- Peirce, Charles Sanders (1992) [1867-1893]. N. Hauser and C. Kloesel (eds.). *Essential Peirce: Selected Philosophical Writings, vol. 1 (1867-1893)*. Bloomington and Indianapolis: Indiana University Press.

2. Peircean Semiotics

- ✔ Human Mind as a Semiosis
  - Peircean semiotics allows us to conceive of a huge semiosis called the self, which, as it experiences various phenomena in the outside world, adopts external semiosis as part of itself, establishes adaptive habits and grows up
  - Peircean semiotics thus shows the way how signs, especially symbols, are connected to their objects and **establish 'meaning'** through a huge symbolic process, namely a human as semiosis, which has undergone a process of habit establishment.

2. Peircean Semiotics

In the context of AI research and Robotics...

- ✔ The human mind is a huge **symbol process**.
- ✔ Such a conception of symbols is completely different from the concept of ‘symbol’ assumed by traditional symbolic AI.

∴ Peircean concepts
preferable for our robotics

- ✔ Symbol
- ✔ Interpretant
- ✔ Semiosis (sign process)

SYMBOLIC SEMIOSIS

2. Peircean Semiotics

- ‘meaning’ of symbols explained from a pragmatist viewpoint
  - ‘Beer glass’
    - ‘you can drink beer tastily with it’
    - ‘you can hold a banquet with it and get along with someone’
  - ‘hard’ thing
    - ‘even if you rub various things against it, it would not get scratched’

✔ The pragmatist method does not attempt to give a definition that can be descripted in a dictionary-like form. Symbols make sense in the light of the accumulation of practices we have developed over the years. The meaning of symbols is plastic and even can change according to our future activities.

3. Symbol Emergence Systems

- How can robots communicate with humans?
- What exactly is ‘meaning’ for robots and humans?

- By adopting the ideas of Peircean semiotics, these questions can be answered.
  - ✔ humans have established their symbol function as semiosis, and hence their own selves that can communicate with others.
  - ✔ To Reconstruct in robots these processes is the constructive approach behind Taniguchi’s symbol emergence in robotics (Taniguchi et al., 2016)
- Let's take a closer look at Taniguchi’s theory of symbol emergence systems...

- Taniguchi, Tadahiro; Nagai, Takayuki; Nakamura, Tomoaki; Iwahashi, Naoto; Ogata, Tetsuya; Asoh, Hideki (2016). “Symbol emergence in robotics: A survey”. *Advanced Robotics* 30, 11-12, pp. 706-728.

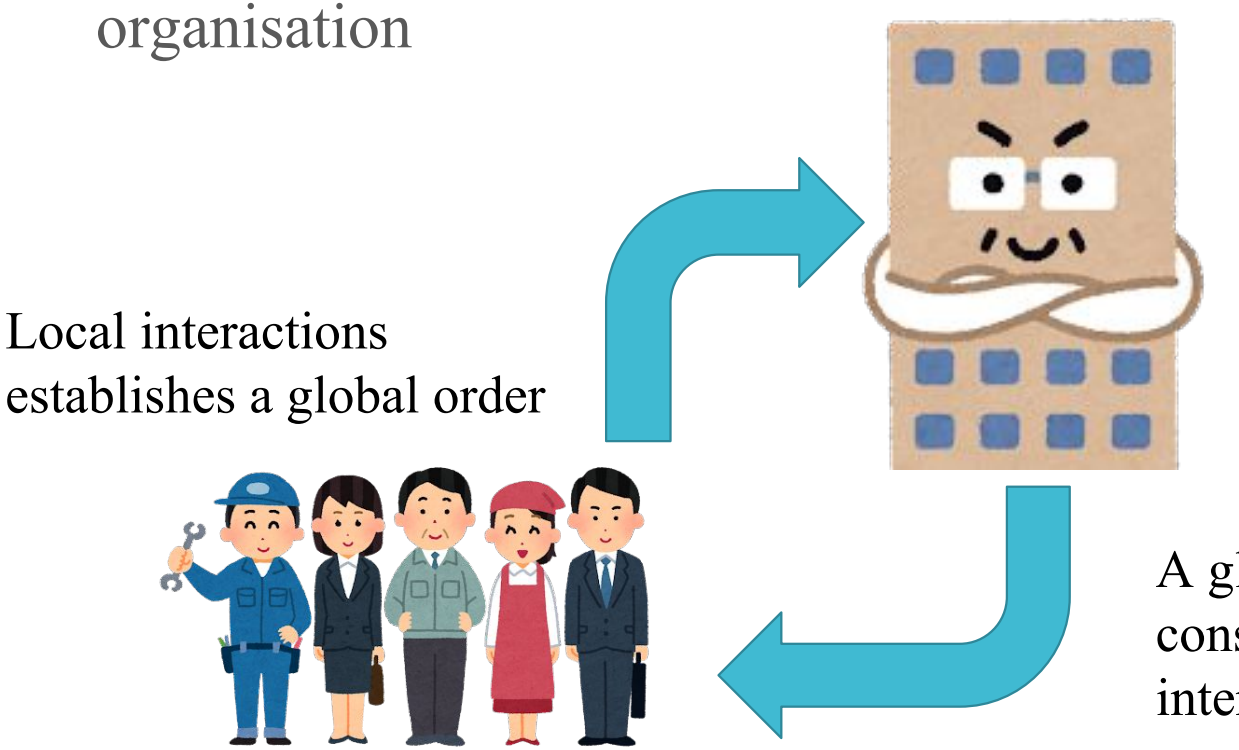
3. Symbol Emergence Systems

- ✔ Emergence Systems
  - A social system is made up of human beings
  - A living organic system is made up of cells
- ✔ components can vary depending on the theory.
  - Ex) Luhmann developed a theory of social systems based on autopoiesis theory by defining the component of a social system as communication (Luhmann, 1984)
- ✔ components operate autonomously and at the same time depend on their interaction.
  - The micro-macro loop: a bidirectional process in which the global order emerges in a bottom-up manner, through local interactions between the components of the system, and the global order thus created becomes a boundary condition that governs the local interactions between the elements in a top-down manner.

- Luhmann, Niklas (1984). *Soziale Systeme: Grundriß einer allgemeinen Theorie*. Frankfurt: Suhrkamp. (English translation: *Social Systems*. Stanford: Stanford University Press, 1995)

3. Symbol Emergence Systems

- ✔ ‘emergence’ means that these micro-macro loops bring about the acquisition of new functions, traits, behaviours, etc. in the system.
- ✔ An example of a emergent system: a company organisation



3. Symbol Emergence Systems

- ✔ The system of symbols used by humans can be described as a kind of emergence system
- ✔ The process by which humans understand the meaning of symbols and become proficient in their manipulation is a process of bottom-up change and adaptation
- ✔ However, it is not enough for an individual to form a symbol system within themselves to be able to communicate with others.
  - Common vocabulary
  - Shared beliefs

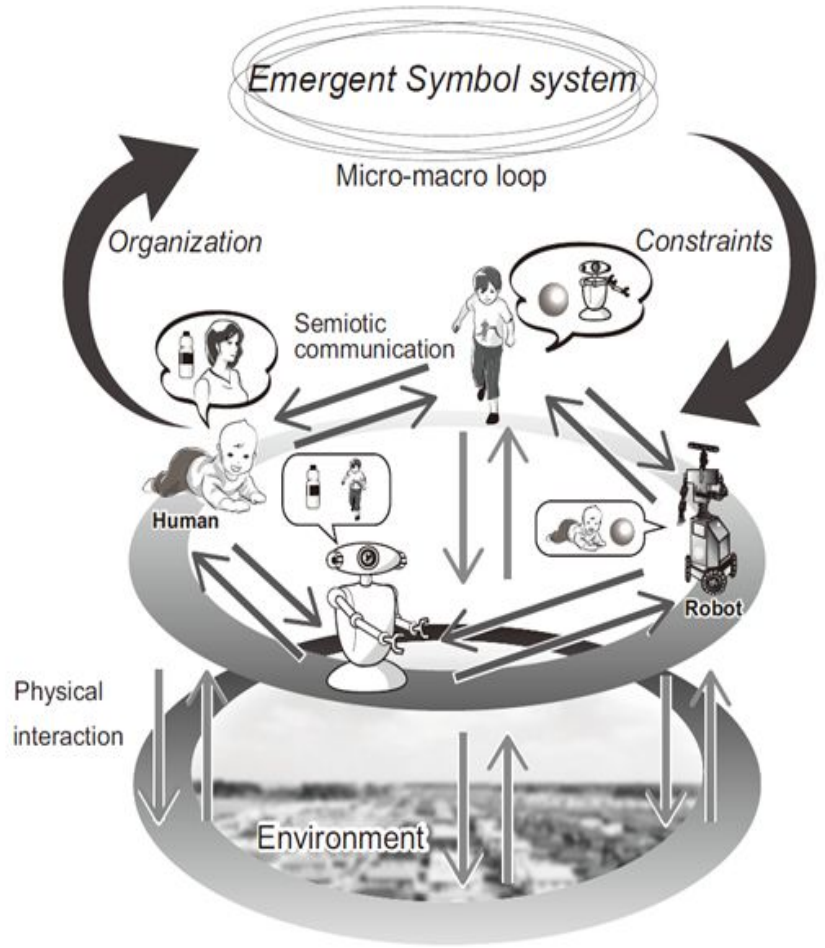
3. Symbol Emergence Systems

- ✔ The formation of the global order of the symbolic system enables each agent to use it to realise cooperation with others through symbolic communication
- ✔ This symbolic system also constrains our behaviour.
- ✔ There is a bi-directional bottom-up and top-down process in the system of communication through symbols.
  - a micro-macro loop exists here
  - Symbolic communication is an emergent function in the symbol emergence system

[Explanations of symbol emergence systems in this secton are based on Taniguchi's book written in Japanese: 谷口 (2014)]

- 谷口忠大 (2014)『記号創発ロボティクス――知能のメカニズム入門』講談社

4. Symbol Emergence in Robotics



- Figure 1 depicts an overview of a symbol emergence system consisting of multiple agents, such as people and future robots.

Figure 1:

Overview of a symbol emergence system [cited from: Taniguchi et al., 2016]

- Taniguchi, Tadahiro; Nagai, Takayuki; Nakamura, Tomoaki; Iwahashi, Naoto; Ogata, Tetsuya; Asoh, Hideki (2016). "Symbol emergence in robotics: A survey". *Advanced Robotics* 30, 11-12, pp. 706-728.

4. Symbol Emergence in Robotics

- ✔ ‘Symbol emergence in robotics’ adopts a constructive approach to symbol emergence systems, using AI and robotics technologies.
- ✔ ‘Symbol emergence in robotics’ has so far developed computational models that can reproduce certain parts of symbol emergence systems. In particular, a computational model representing a computational process of internal representation formation has been studied in relation to concept and category formation and lexical acquisition.
  - For example: Nakamura et al. (2009) proposed a multimodal latent Dirichlet allocation (MLDA) and showed that a robot can find many object categories by integrating multimodal information.

- Nakamura, Tomoaki; Nagai, Takayuki; Iwahashi, Naoto (2009). “Grounding of word meanings in multimodal concepts using LDA”. *IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 3943-3948.

5. Peircean Philosophy of Mind

- What will be the self-perception of human agents in future symbol emergence systems?

- Peirce's way of understanding the human mind involves ideas similar to those of the 'extended mind' as discussed in Clark and Chalmers (1998).

✔ In this case, the individual's mental processes are established with a hybrid system consisting of the brain and the notebook

- Clark, Andy and Chalmers, David. (1998) "The extended mind". In: *Analysis*, [S.l.], volume 58, issue 1, p.7-19.

5. Peircean Philosophy of Mind

✔A tricky problem arises:

Can we say that Otto's self extends to the notebook?

- In Peirce's view, the self is one huge semiosis, which continues to grow as it incorporates the semioses of the external world.

✔We can say that Otto without a notebook is one semiosis, and Otto with a notebook is also a semiosis called Otto, which has been updated by incorporating the semiosis of the notebook.

- For more detailed arguments, see: Kato,T.(2015) "A Peircean Revision of the Theory of Extended Mind". *Cognitio: Journal of Philosophy*, v.16, n.1.

5. Peircean Philosophy of Mind

Peirce's theory of mind suggests a more flexible view of the self or mind

- ✔ You can choose the semiosis you regard as your own self in different ways depending on the situation
- ✔ You can conceive of your own self on various scales or levels.
  - You can choose, for example, your own self as a member of a family, a member of an organisation, or a member of a society, etc., depending on the situation

- This property of Peirce's theory of mind, which allows us to conceive of mental process that incorporates the semioses of different communities, is of particular interest to contemporary anthropologists. Kohn (2013)

- Kohn, E. (2013) *How Forests Think: Toward an Anthropology beyond the Human*. Berkeley, CA: California University Press.

5. Peircean Philosophy of Mind

- In light of these ideas of Peirce, a human being who finds herself in a community that includes robots will come to regard herself living together with the robots as her own self.
- both humans and robots will be responsible for the emergence of symbolic system
- The task of envisioning the concrete form of such new symbol systems is left to future research. However, it should at least be pointed out that by following Peirce's theory of mind, the emergence of new practices, functions, intelligence, etc. in a symbol emergence system that includes robots as agents can be envisioned more flexibly and vividly.

6. Symbol Emergence Systems as Future Communities of Inquiry

✔ the idea of ‘regulative assumptions’

- ‘reality’ (*)
  that which must be assumed in order to advance scientific inquiry
- On the basis of the assumption of ‘reality’ as a strict fact of the external world, independent of the workings of the human mind, the practice of scientific inquiry is founded.

(*) Peirce (1992[1877]: 136-7)

- Peirce, Charles Sanders (1992) [1867-1893]. N. Hauser and C. Kloesel (eds.). *Essential Peirce: Selected Philosophical Writings, vol. 1 (1867-1893)*. Bloomington and Indianapolis: Indiana University Press.

6. Symbol Emergence Systems as Future Communities of Inquiry

James' criticism against Peirce

- ✔ the pragmatic maxim ought to "be expressed more broadly than Mr. Peirce has expresses it" (James 1975 [1907]: 258-59)
- ✔ the "ultimate test for us of what truth means is indeed the conduct it dictates or inspires [...] I should prefer to express Peirce's principle by saying that the effective meaning of any philosophic proposition can always be brought down to some particular consequence, in *our* future practical experience" (James 1975 [1898]: 124, italicisation by the lecturer)

- If we take James's statement as it stands, it seems as if truth could depend on our subjectivity.
- However, such a thought is unacceptable to Peirce
- Peirce's pragmatism involves the idea of a community of inquirers who aim for a truth that is not dependent on human subjectivity.

- James, William. (1975 [1907]) *Pragmatism: A New Name for some Old Ways of Thinking*. In *The Works of William James*, vol.1. Cambridge MA: Harvard University Press.

6. Symbol Emergence Systems as Future Communities of Inquiry

According to Peirce's refined pragmatism...

- 'truth' means a belief that would never be revised even when the inquiry is pursued as far as it can effectively advance and enough evidence and arguments are presented
- assumptions that must be posit in the course of inquiry, such as the concept of reality, are called 'regulative assumptions'.

- Misak (2000) argues that not only scientific inquiry, but also inquiry in ethics and politics can be seen as setting up regulative assumptions in each field and aiming for truth in the sense that Peirce describes.

- Misak, Cheryl. (2000) *Truth, Politics, Morality: Pragmatism and Deliberation*. London and New York: Routledge.

6. Symbol Emergence Systems as Future Communities of Inquiry

- What insights does the Peircean idea bring to the theory of symbol emergence systems if we regard the various kinds of communities of inquiry as collective semioses, each of which evolves with its own regulative assumptions of inquiry?
  - consider a community of inquiry consisting of humans and robots.
  - In the community of inquiry, regulative assumptions act as top-down constraints. On the other hand, these regulative assumptions are established through the accumulation of local practices of inquiry.
  - each of various communities of inquiry can be considered to act as a symbol emergence system

6. Symbol Emergence Systems as Future Communities of Inquiry

- Future robots will join these communities of inquiry and experience a co-creative learning process with humans.

- the semiosis of the entire community of inquiry is renewed and symbol emergence proceeds under the interaction between humans, robots and the environment.
- How will the semiosis of human beings change in the symbol emergence system that develops together with robots? The theory of symbol emergence systems should also consider this point with what we are entrusted from Peirce.

Conclusion

- ✔ The history of symbols in AI and robotics was briefly explained, and symbols were reinterpreted from the perspective of Peircean semiotics: symbols as semioses.
- ✔ The theory of symbol emergence systems developed on the basis of Peircean semiotics was reviewed, and research on symbol emergence in robotics was briefly outlined.
- ✔ The insights of Peircean thought that could make a further contribution to the research of Taniguchi were examined.

Conclusion

- ✔ Symbol emergence in robotics has the potential to bridge AI and semiotics.
- ✔ Further interdisciplinary discussions are expected at the intersection of AI, robotics and semiotics, namely, ‘symbol emergence in robotics’.

Muito Obrigado!

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