Jst Erato Asada Project

Can Causality Detected by Transfer Entropy Lead Acquisition of Gaze Following?

○Hidenobu Sumioka(1),(2)　Yuichiro Yoshikawa(1)　Minoru Asada(1),(2)

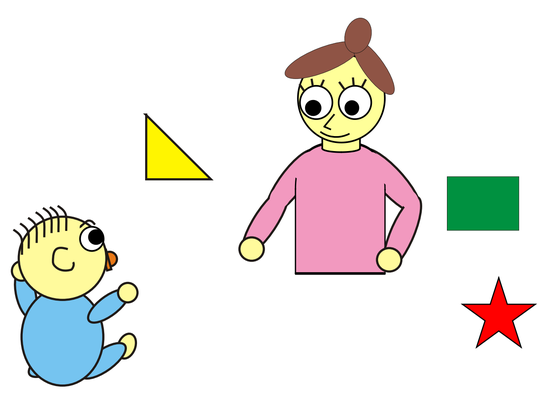
(1) JST Erato Asada Project
(2) Emergent Robotics Area, Dept. of Adaptive Machine System,
Graduate School of Eng. Osaka Univ.
Yamadaoka 2-1 Suita, Osaka 565-0871, Japan

Abstract

Many observational studies have suggested that human infants acquire various social skills through interactions with their caregivers. Some causal structures in the interactions seems to help such development of social skills. Previous synthetic studies have focused on the causality to model the developmental process of gaze following, i.e., the behavior of looking at the same object another person is looking at. As a result, they have proposed learning methods without any explicit instructions for gaze following. The causal structure between a perception variable (the caregiver's face directions or individual objects) and an action variable (gaze shift to the caregiver's face or object locations) is given in advance to learn gaze following. However, such a structure is expected to be found by the robot through the interaction experiences. This study investigates how the transfer entropy, that is an information theoretic measure, can be used to quantify the causality inherent in the face-to-face interaction. In the computer simulation of human-robot interaction, we examined which pair of perceptions and actions are selected as the causal pair and showed that the selected pairs can be used to learn a sensorimotor map for achieving gaze following.

Background

○ Development of social skills in infants

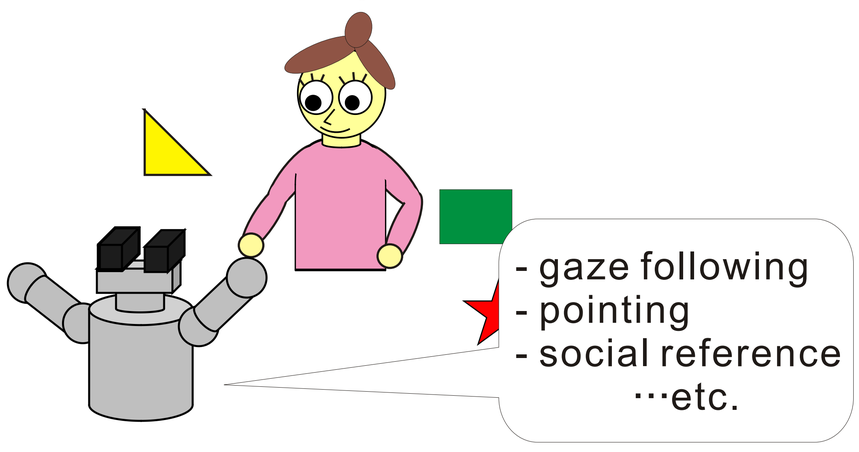


- Caregivers socially respond to infant behavior. [Dunham and Dunham, 95]
- Infants understand a simple causal structure. [Cohen and Amsel, 98]

Hypothesis:

Development of social skills is led by understanding causal structures in interaction with the caregiver.

○ Building a social robot that can acquire social skills

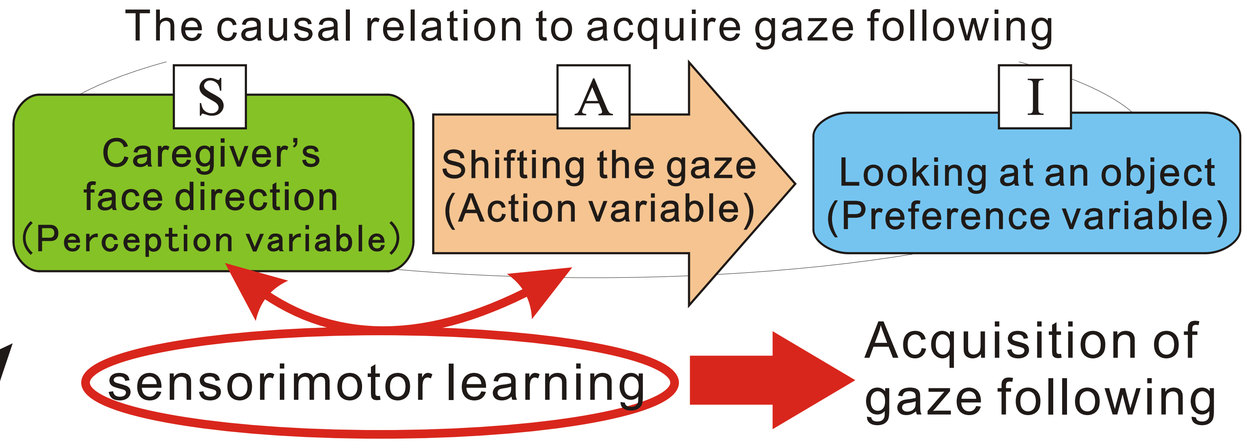


The robot needs to
- **detect causality in interaction.**
- acquire social skills based on the detected causal structure.
- acquire new skills using the learned skills

Previous model of acquisition of gaze following [Nagai et al, 03]

Assumption:
The direction of the caregiver's gaze implies that there is something salient.

The causal relation to acquire gaze following



The designer had to decide which pair of variables(S,A,I) forms a causal relation to acquire gaze following.

→ Modeling human interaction is not trivial.

Purpose: Building a robot that automatically selects out pairs of perception and action variables that form a causal structure.

Question: Is transfer entropy useful to detect the causality in the interactions with a caregiver?

Quantification of the causality in interaction with a caregiver (Transfer entropy [Schreiber, 00])

Transfer entropy is an information theoretic measure that shares some of the desired properties of mutual information but also takes account of the dynamics of information transport between stochastic variables.

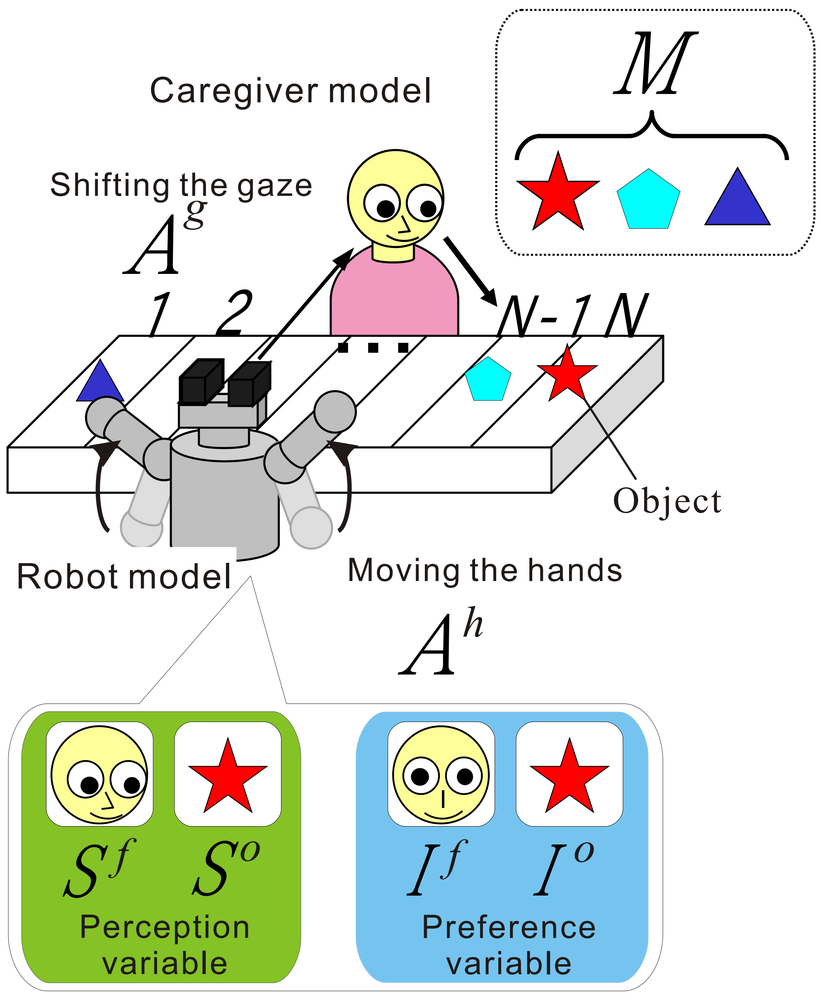
The transfer entropy that indicates the influence of a stochastic variable Y on a stochastic variable X is calculated by

$$T_{Y\to X} = \sum P(x_{t+1}, x_t, y_t)\log\frac{P(x_{t+1}\mid x_t, y_t)}{P(x_{t+1}\mid x_t)}$$

The influence of the pair of an action variable (A) and a perception variables (S) on a preference variable (I) is calculated: X=S×A, Y=I

Face-to-face interaction between caregiver and robot

Can the robot find the combination to acquire gaze following in face-to-face interaction using the transfer entropy?



○Caregiver model

- Two strategies of shifting the gaze
  - Communicative strategy:
    Observing an object or the robot(p_c^c)
    Three options:
    -RJA process (the probability P_{RJA} when seeing the robot)
    Looking at an object that the robot is looking at
    -IJA process (the probability P_{IJA} when seeing an object)
    Looking at an object and the robot alternatively
    -Random process
    Selecting a target randomly
  - Completely random strategy:
    Observing a spot on the table or the robot ($1\text{-}p_c^c$)

○Robot model

- Observing a spot on the table or the caregiver
- Moving the hands when looking at an object

* The transfer entropy that focuses on the combination of a perception variable (S) and an action variable (A):

$$TC_{k,\,l,\,m} = T_{A_k,S_l \rightarrow I_m} - T_{A_k \rightarrow I_m}$$

The combination to learn gaze following: A^g, S^f, I^o

Transfer entropy in face-to-face interactions

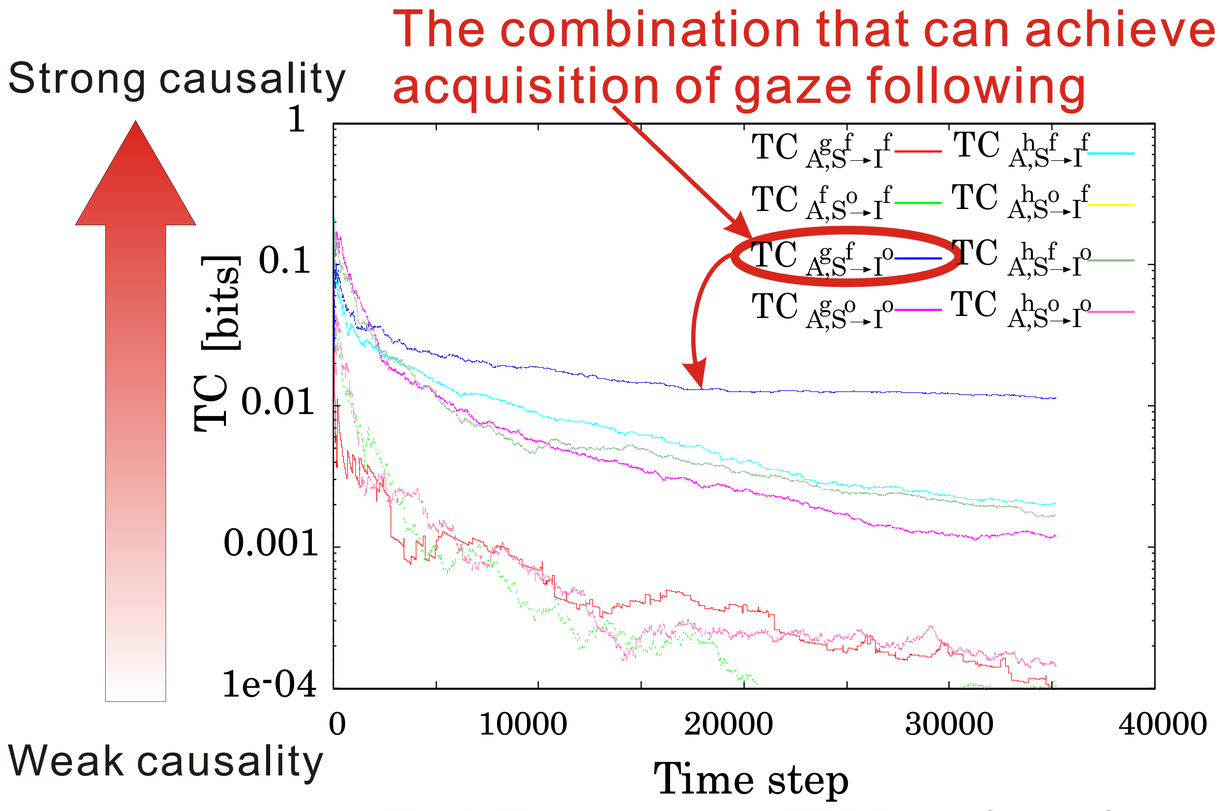


Fig.1. Time courses of TC ($N = 9$, M=3, p_c^c=1.0, p_{IJA}=0.2, p_{RJA}=0.8)

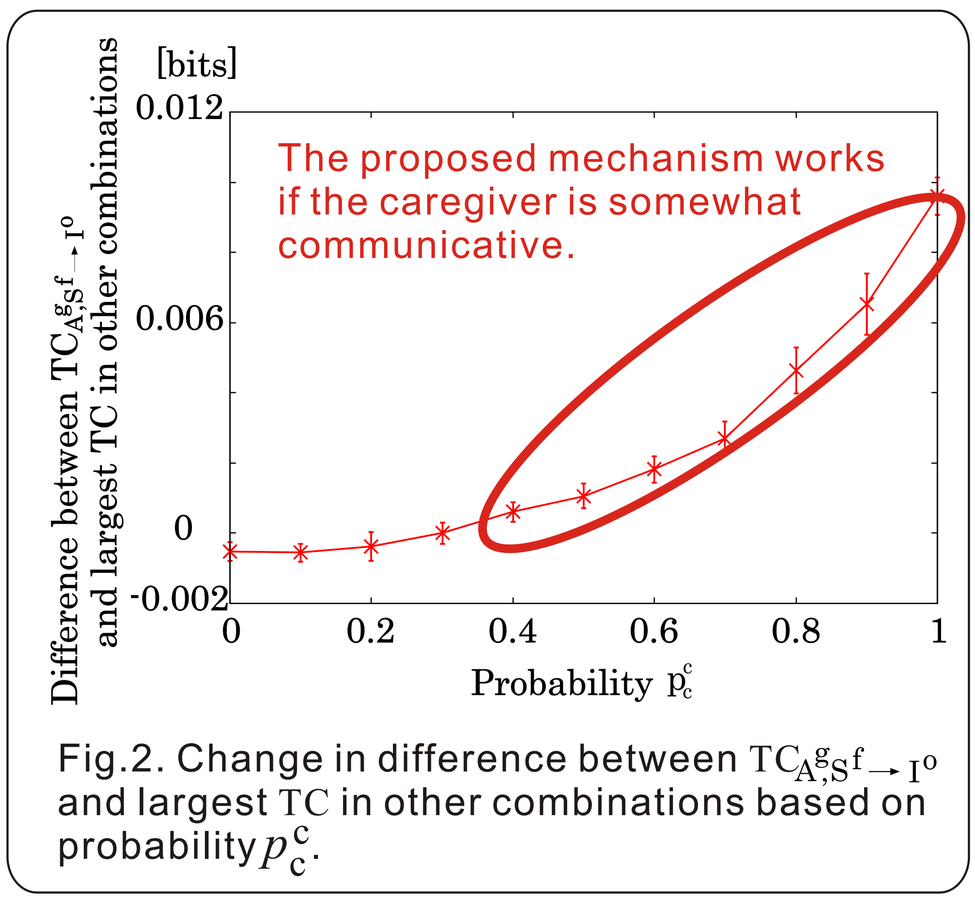


Fig.2. Change in difference between $TC_{A^g,S^f \rightarrow I^o}$ and largest TC in other combinations based on probability p_c^c.

The robot was able to detect a causal combination of variables to learn gaze following by using transfer entropy.

Learning gaze following with the detected causal variables

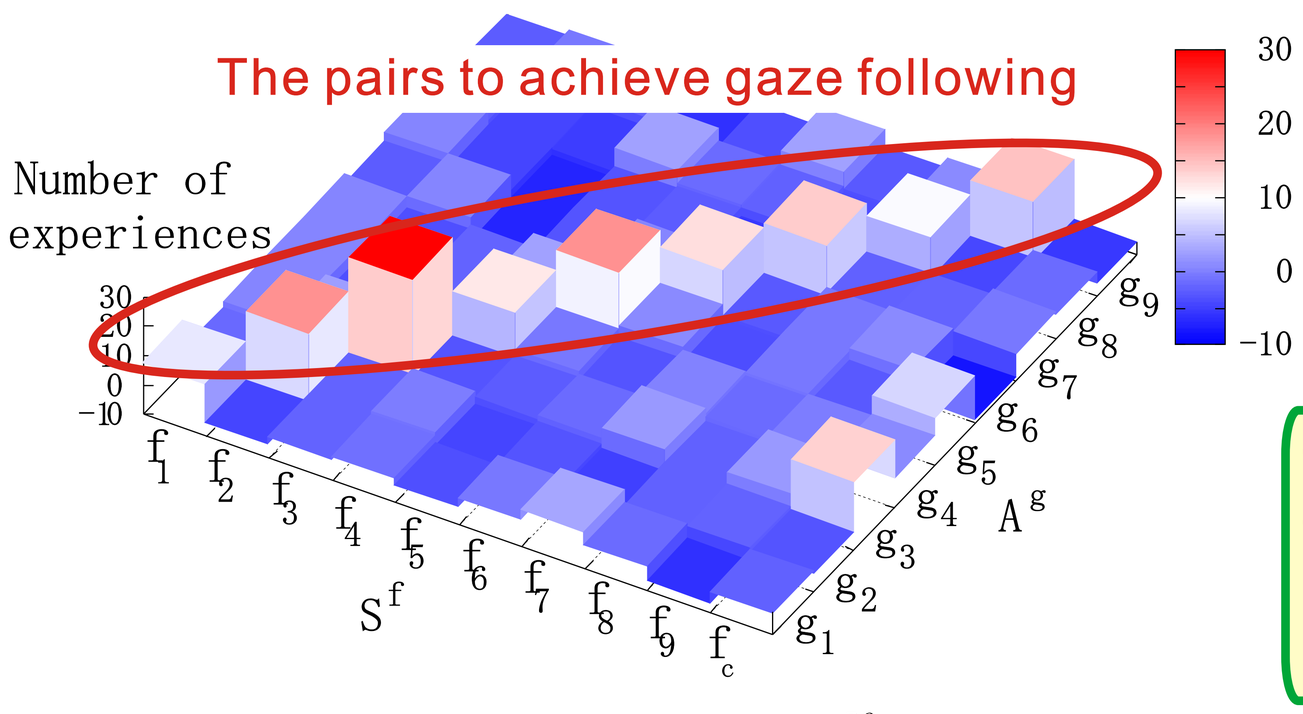


Fig.3. Distribution of experiences to I^o=1 in interactions between a caregiver and a robot.

Does the detected pair (A^g, S^f, I^o) allow the robot to have experience to enable learning gaze following?

The sensorimotor mapping from S^f to A^g enables the robot to acquire gaze following as predicted by Nagai's work [Nagai et al.,03].

Future works

- Building a mechanism to acquire various social skills.
  Does each developmental process of social skills influence each other?
- Implimenting the proposed mechanism into a real robot and observing human-robot Interations.
  Can the robot find combinations related to mind-reading and language communication?