Imitation Behaviour Evaluation in Human Robot Interaction

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Motivation

To recognize being imitated by others as well as to imitate others is a crucial milestone in child development.
Our Goal: To investigate whether a robot can recognize being imitated by a human by detecting correlation between the visual and the motor data

Comparative Experiment

Experimental setup (Infanoid, the robot used in the experiment, has been developed in NICT, Japan [Kozima and Yano, 2001].)

Calculating correlation between the visual and the motor data detected when:

(a) Robot: randomly move both arms
Human: *randomly move* both arms while holding coloured objects

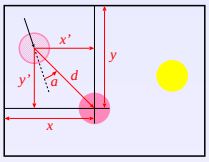
(b) Robot: same as in (a)
Human: *imitate robot's movement* while holding coloured objects

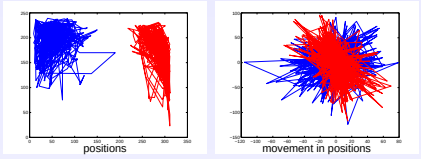
(c) Robot: randomly move both arms while holding coloured objects
Human: none

(The objects were used to detect the R's / the H's hands.)

Visual Data

- $(x_1,\ y_1)$, $(x_2,\ y_2)$: positions of objects in camera image
- $(x'_1,\ y'_1)$, $(x'_2,\ y'_2)$: movement in positions
- $(\alpha_1,\ d_1)$, $(\alpha_2,\ d_2)$: movement in angle and distance

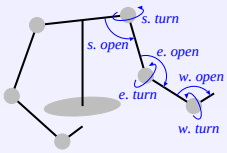




Example of collected data

Motor Data

- angles of shoulder open/turn, elbow open/turn, and wrist open/turn of left arm
- angles of shoulder open/turn, elbow open/turn, and wrist open/turn of right arm



Calculating Correlation

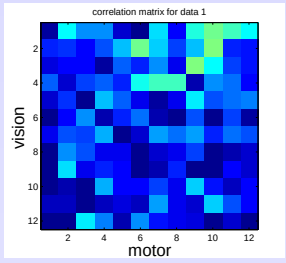
Correlation between two sensors X_i and X_j:

$$d(X_j, X_i) = H(X_i|X_j) + H(X_j|X_i)$$

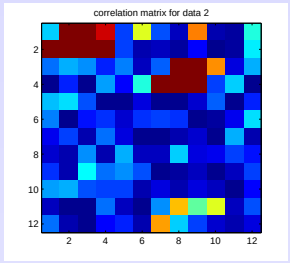
where

$$H(X_j|X_i) = -\sum_{x_i}\sum_{x_j} p(x_i, x_j)\log_2 p(x_j|x_i)$$
$$p(x_j|x_i) = p(x_j, x_i)/p(x_i)$$
$p(x_i)$: the probability mass function

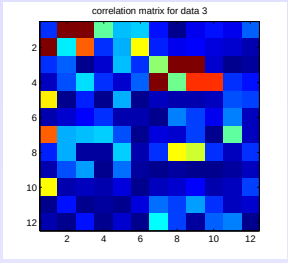
Results



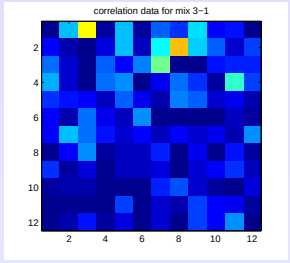
(a) R: random, H: random



(b) R: random, H: imitate R



(c) R: random & observe itself



(d) vision: (c), motor: (a)

Correlation matrices between visual and motor data

(a) no correlation

(b) high correlation between
$(x_{1,\ 2},\ y_{1\ ,2})$ and (shoulder open/turn, elbow open/turn)
low correlation between
$(\alpha_2,\ d_2)$ and (shoulder open/turn, elbow open/turn of right arm)

(c) high correlation between
$(x_{1,\ 2},\ y_{1\ ,2})$ and (shoulder open/turn, elbow open/turn)

(d) no correlation

➔ The correlations between *the positions of the human hands detected in the vision* and *the angles of the robot's arms* were found when the human was imitating the robot's movement.

➔ In contrast to the former work [Hafner and Kaplan, 2005], in which a robot used the visual data directly derived from the motor data of another robot, this result suggests that a robot can recognize being imitated by another *by using its own sensor data.*

Future Issues

- To examine whether the robot can create an interpersonal map [Hafner and Kaplan, 2005] using these data
- To investigate what other kinds of sensor data help the robot to recognize being imitated

References

Hafner, V. and Kaplan, F. (2005). Interpersonal maps and the body correspondence problem. In Proc. of the 3rd International Symposium on Imitation in Animals and Artifacts, pp. 48-53.

Kozima, H. and Yano, H. (2001). A robot that learns to communicate with human caregivers. In Proc. of the 5th International Workshop on Epigenetic Robotics, pp. 47-52.

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