Berthouze, L., Kaplan, F., Kozima, H., Yano, H., Konczak, J., Metta, G., Nadel, J., Sandini, G., Stojanov, G. and Balkenius, C. (Eds.)
Proceedings of the Fifth International Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems
Lund University Cognitive Studies, 123. ISBN 91-974741-4-2

What is Animacy in Dynamical Movement?

Hiroyuki Kuwamura, Tomoyuki Yamamoto and Takashi Hashimoto
School of Knowledge Science, Japan Advanced Institute of Science and Technology (JAIST)
Nomi, Ishikawa, 923-1292 Japan
e-mail: (h-kuwa,t-yama,hash)@jaist.ac.jp

What sort of movements of an object make it look alive? How do we feel aliveness in a robot moving? This sense, animacy, is experimentally investigated for moving of objects. There are many artifacts that remind us animacy, e.g., animation movie characters, dolls or human gures in ne arts. We often feel animacy for non-living things, or even abstract objects (Tremoulet and Feldaman, 2000) (Nakamrura and Sumi, 2002). One possible reason is personi cation. Johansson (Johansson, 1973) showed that even complicated shape can be easily recognised when moving objects can be viewed as a human movement. However, this concept is not concerned about the quality of movements, which we are interested in.

We performed a psychophysical experiment where a dynamical system evolves to life-like system by interactive evolution computation method. In the model, the genotype codes the parameters of a dynamical model. The model consists of combined oscillators on two dimension space with harmonic interaction (i.e., linear spring), see g.1A. The boundary condition is periodic. The number of points are 3, 4 and 5. For each point, there are four parameters: k_S (spring constant for oscillation of itself), k_I (spring constant for interaction with nearest neightbour), (initial position) and v (initial velocity). The points move only in horizontal direction. The phenotype dynamics, is shown to a subject as a set of moving dots on a computer display. Display image area is divided into 12 compartments where individual models are presented.

Evolutional process is based on the selection by the subject. At each generation, one or two individual models out of 12 are selected for next generation and subjects do not explicitly tune parameters of the model. Mutation processes are random bit ip mutation or crossover, depending on the number of selected individuals. We adopted Gray coding for encoding dynamical parameters and gradual evolution is obtained by mutation.

15 healthy subjects without visual di culty participated in the experiment (ages: 23 to 28). In typical session, a subject was asked to select one or two most "life-like" individuals in each generation (up to 40 genelations). The experiment consisted of 3 trial runs, followed by 3 sessions, where the number of dots increased by one after each session (from 3 to 5). After the experiment, the subject was asked to ll out a questionnaire.

All subjects reported that they felt animacy in their products, of which the majority of the subjects reported a set of dots that resembles a "body". This may be due to personi cation.

We examined what kind of movements of the "dots" gives animacy. The evolutionary process is logged and analysed. According to the reports of subjects, we de ned stagnating points, where the same genotype is selected for more than 5 generations, as products. 77 products are obtained (3 to 8 per subject). Alternate data is randomly generated products by using random numbers as genotypes. The number of sample is equal to total number of trials, 135. By visually observing these products, we classi ed 9 sorts of dynamical features as follows.

(SA) Stroke. Like a sh swimming, dots form a body (i.e., almost in phase) and stroke is obviously seen. **(SB)** Stroke and cluster coexist. **(SC)** Stroke is not clearly seen. **(CA)** Clustering. Each dot form in-phase or anti-phase clustering with neighbour. Periodic trajectory is obviously seen. **(CB)** Partially disordered clustering. **(CC)** Shows reorgnisation of clusters. **(CD)** The dots look broken into two clusters (i.e., bodies), due to large di erence of amplitude. **(CE)** Clustering. Top and bottom dots are in phase. **(J)** Jerky. Cluster is formed but jerky movement is often seen. **(Other)** Unclassi able. Their relative frequencies are shown in g.1B.

The classi cation is subjectively done but based on the results of questionaires. The subjects suggested they felt animacy for stroking pattern. This pattern is de ned as travelling wave pattern. Also, a "walking human" like pattern is suggested. We regard this pattern as alternating oscillation and de ned it as cluster pattern. Based on these two patterns, we visually observed time serieses of the pheno type dynamics and identi ed 9 features shown above.

We are currently working on a numerical method to classify the results will be reported in elsewhere. It is important to note that human impression is based on implicit ltering. For example, clustered movement can be seen when all points are moving in the same direction with small di erences. In such case, trend must be subtracted. Then before we adopt statistical testing, many possible patterns of transformation of coordinates

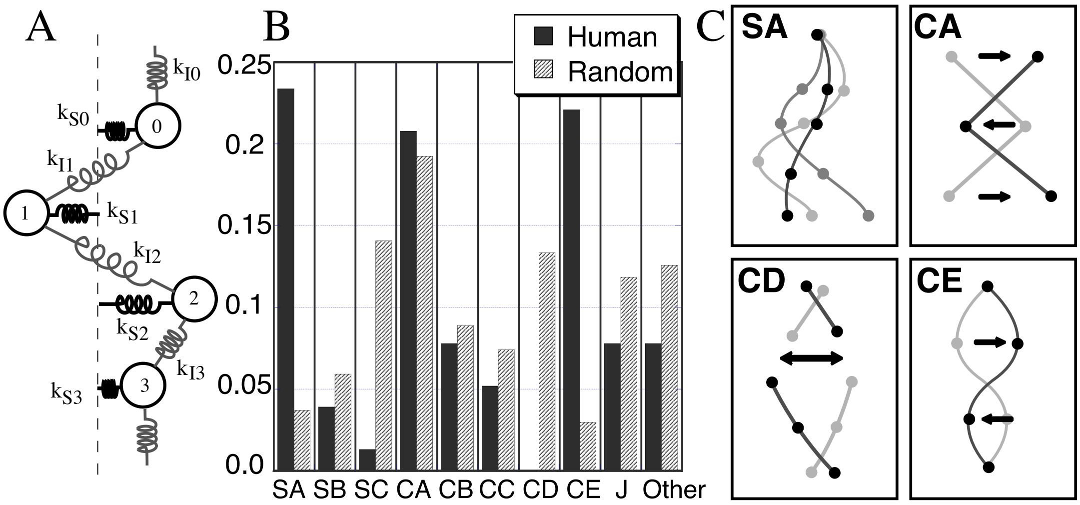

Figure 1: A: model. B: relative frequency of products classi cation. C: schematic representation of movements.

are required.

The di erence between two distributions of frequency are accepted by χ^2 test (0 01). Between human selection and randam gereration conditions, signi cant di erences (larger than sum of standard deviations, assuming multinomial distribution of equal probability) are seen for **SA**, **SC**, **CD** and **CE**. **SA** and **CE** are positively and **SC** and **CD** are negatively selected by human.

Then we suggest that animacy lies in clear stroke (**SA+** / **SC-**) and oscillation within a body (**CE+** / **CD-**). Since stroke movement is rare in linear system, we are going to adopt nonlinear dynamics to our model and try to nd more features of animacy.

Even abstract objects give rich feelings. If the above features are implemented for a robot, it may look more socialable and may be able to do nonverbal communication with humans. Socialable robots that perform emotional expression (e.g., (Breazeal, 2000)) may be improved by adopting non-constant velocity (i.e., stroke-like) of behaviour or facial movements. Also, stroke-like movement may be important for a robot co-working with humans. A stroke movment includes slow preparatory movement (e.g., wind-up before shooting) and helps to users to predict the robot's behaviour. We believe that animacy can be used as evaluation criteria for quality of communication between humans and robots.

If we establish a criteria of animacy in an objective form (e.g., statistical form), it may contribute to the improvement of learning method. Because method of learning and quality of target are not completely independent, new value standard of quality potentially enhance ability of learning. For example, stroke-like movement is found to be essential part of the mortor skill (Yamamoto and Fujinami, 2004), as phase di erentiation in experts' movements. Then cognition of animacy may lead to self-learning of skillful movement.

References

Breazeal, C. (2000). *Sociable Machines: Expressive Social Exchange Between Humans and Robots.* PhD thesis, Department of Electrical Engineering and Computer Science, MIT.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics*, 14:201–211.

Nakamrura, K. and Sumi, S. (2002). Motion information contributing to the perception of animacy or inamimacy from the motion of a single object (in japanese). *Techinical Report of IEICE*, TIS2001-67, IE2001-206 (2002-01):95–100.

Tremoulet, P. D. and Feldaman, J. (2000). Perception of animacy from the motion of a single object. *Perception*, 29:943–951.

Yamamoto, T. and Fujinami, T. (2004). Synchronisation and di erentiation: Two stages of coordinative structure. In *proceedings of third international workshop on Epigenetic Robotics 2004*, pages 97–104.