The Mirror Self-recognition for Robots

iCubSim at the mirror

Andrej Lucny
Department of Applied Informatics
FMFI, Comenius University
Bratislava, Slovakia
lucny@fmph.uniba.sk

***Abstract*—We introduce a simple example of artificial system which aims to mimic the process of the mirror self-recognition - ability limited to very few species. We assume that evolution of the species is reflected in the structure of the underlying control mechanism and design modules of the mechanism, concerning its incremental development. On this example, we also demonstrate modular architecture suitable for such task. It is based on decentralization and massive parallelism and enables incremental building of control system which is running in real-time and easily combines modules operating at different pace.**

Keywords—the mirror self-recognition; robot iCubSim; Agent-space architecture

I. Introduction

Seeing in the mirror, we recognize ourselves. However child less than eighteen months old is rather looking for another person behind the mirror. In nature, the mirror self-recognition is present only in exceptional cases, for instance chimpanzees recognize themselves in the mirror, while cats do not. Can a robot recognize itself in the mirror? And what is the origin of the self-recognition ability? We follow Scassellati and Hart [3], who suppose that a robot should recognize itself in the mirror due to perfect correlation between body movement and the image seen in the mirror. Unlike them and like Takeno [8] we use a very simplified body model.

II. Testbed

Using the simulator of the humanoid robot iCub [7] we added a camera shooting the area in the front of the monitor with the robot rendered image, we create a control system on which we can examine how the mirror self-recognition emerges from basic mechanisms. This enables us to establish interaction between the virtual robot and human sitting at the monitor and later between the robot and its image reflected to the camera by the mirror. The simulator has almost perfect model of the robot body. However for our purposes we intend to simplify it, thus we move a single joint – the joint moving head from side to side. In this way the body model is simplified to a single number – the angle of the robot head inclination.

III. Architecture

For examination of mechanisms underlying the mirror self-recognition process, we employ a modular framework (Agent-Space Architecture [5]) which enables us to let the control system emerge from the parallel course of simpler modules and from their mutual interactions. Agent-Space Architecture is a software tool for building modular control systems of robots, running in real-time. It is strongly based on ideas of Brooks' subsumption architecture [1] and Minsky's society model of mind [6] [4]. Within the framework we define operation of individual modules and connect various module outputs to various module inputs (many:many) regardless the fact that each module can operate at different pace. Such combining of either really slow or really fast processes is possible due to all data produced by a module (producer) being written onto a blackboard (called *space*) and processed later, when another module (consumer) is ready to process them. These written data remain on the blackboard until they are rewritten by the same or another producer, or their time validity expires. Finally the data exchange supports also hierarchical control and its incremental development, e.g. module has to define sufficient priority for written data – otherwise it would not be able to rewrite their previous value already written on the blackboard.

IV. Mechanisms

Now we can try to implement the system, using which we are able to evaluate correlation between own body movement and the seen image movement. We aim to implement a working demo following biological relevancy of our approach, based on knowledge about the above-mentioned species.

A. Body model (proprioception)

The body model is provided by the iCubSim simulator, thus we need to implement just its control and monitoring from the blackboard. We implement a module *motor* which reads an intended joint position *intention* from the blackboard, communicates with the simulator (via yarp rpc protocol) and as a result, it writes *proprioception* to the blackboard which represents a real joint position (Fig. 1). In parallel, the added camera regularly provides a new image to the blackboard.

B. Mirroring

As we aim to compare the body model (i.e. value *proprioception*) with the *image* captured by the camera, we need to get an analogical model from the image. This approach is still biologically relevant since several species are proven to obtain such ability (mirror neurons). (How such ability has emerged and evolved, is not the subject of our exploration – it is only limited to the implementation of this ability.) Since we take into account both interaction between the robot and human and interaction between the robot and its image in the mirror, we combine two specific methods which output the same data onto the backboard – the model of the seen image (the *model* value in Fig. 1).

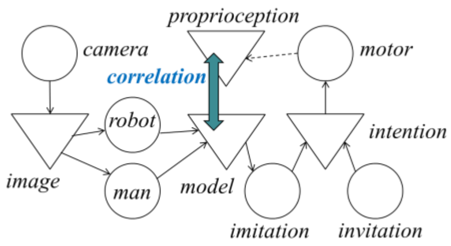

Fig. 1. The modular structure of the mirror self-recognition system

Fig. 2. The iCumSim robot following its own image in the mirror

For the iCubSim image processing (we rotate a printed picture of iCubSim in front of the camera) we employ the SURF method. SURF provides projection of given template to the image seen from which we can easily calculate inclination of the template. For the processing of human image (interacting person is moving his head in front of the camera) we use combination of Haar face detector and CamShift tracking: the Haar detector detects face in the upright position and sets up template for CamShift to track. The projection of the template to the seen image calculated by CamShift provides us with the required head inclination. All algorithms employed are available in OpenCV library (www.opencv.org).

C. Imitation

The correlation of these two comparable models can only be evaluated by their changes through time therefore both robot and human have to be put in motion. One of the mechanisms, that can provide it, is imitation. Due to the utilized mirroring, a passive imitation can be implemented by direct copying of values of the body model seen (i.e. the *model* value) into the robot's body model (i.e. the *intention* value). As a result, iCubSim imitates side to side movement of one's head when moving in front of the camera. Optionally we can also implement the active part of imitation, which can be called the invitation to imitation and obtains a higher priority than the passive imitation and occasionally generates side to side movement of the robot's head when the body seen does not move. However we found out that even slight inaccuracies in the model evaluation are sufficient to induce the imitation process.

D. Social modelling

Imitation process provides us with the data of correlation between the body owned and the body seen. When an individual lives within a society, it is important for him to categorize the data and associate them with the image seen. When such individual meets the mirror, it possibly creates a new category and finds out that the corresponding correlation is unusually high. In fact, it is so high that the image seen can not only be associated with the body model seen, but also with its own body, meaning that it sees itself. Instead of modelling the society, for our purposes, it is sufficient to record the data produced by the two models since the aim of the study is to differentiate the data created when robot encounters human and when robot sees its own image in the mirror.

V. Conclusion

As a result of implementation of the above mentioned mechanisms, when iCubSim's image is reflected into the external camera by a mirror, robot invites himself to imitation and it stays in an interaction with itself for certain amount of time (Fig. 2). Thus correlation between the body model (*proprioception*) and the model of the image seen (*model*) can be evaluated and its unusually high value indicates that the robot sees itself in the mirror. Thus the designed structure of the mirror self-recognition process is partially verified.

As a teaser video can be viewed here:
http://www.agentspace.org/mirror/iCubSimAtTheMirror.mp4

References

[1] Brooks, R. (1999). "Cambrian Intelligence". The MIT Press, Cambridge, MA

[2] Gallup, G. G., Jr. (1970). Chimpanzees: Self Recognition. Science, 167, 86-87.

[3] Hart, J. W. Scassellati, B. (2012). Mirror Perspective-Taking with a Humanoid Robot. In Proceedings of the 26th AAAI Conference on Artificial Intelligence (AAAI-12). Toronto, Canada.

[4] Kelemen, J. (2001). "From statistics to emergence - exercises in systems modularity". In: Multi-Agent Systems and Applications, (Luck, M., Marik, V., Stepankova, O. Trappl, R.), Springer, Berlin, pp. 281-300

[5] Lucny, A. (2004). "Building complex systems with Agent-Space architecture". Computing and Informatics, Vol. 23, pp. 1001-1036

[6] Minsky, M. (1986). The Society of Mind. Simon&Schuster, New York

[7] Sandini, G. - Metta, G. - Vernon, D. (2007). The iCub cognitive humanoid robot: an open-system research platform for enactive cognition. In: 50 years of artificial intelligence, pp. 358-369, Springer-Verlag, Berlin

[8] Takeno, J. (2008). A Robot Succeeds in 100% Mirror Image Cognition. INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS, Vol. 1, No. 4, December 2008