# Learning Hand-Eye Coordination for a Humanoid Robot using SOMs

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## Introduction

Acquisition of hand-eye coordination skills is a prerequisite for more complex behaviors used in social interactions. Pointing gestures are often employed to steer the attention of participants and are thus an integral part of spontaneously flowing human-robot interaction. We propose a biologically inspired model and implement it on a humanoid robot to analyze pointing [1]. The model is based on self-organizing maps (SOMs) and the Hebbian learning paradigm. In the experiment we showed that the robot equipped with such a model exhibits pointing when an object is presented out of reach of its hand.

## Random Motor Babbling

Motor babbling is a **self-exploration** mechanism for acquiring sensorimotor experience. An adapted random motor babbling algorithm [2] was implemented on a **humanoid robot** Nao for learning of left arm postures.

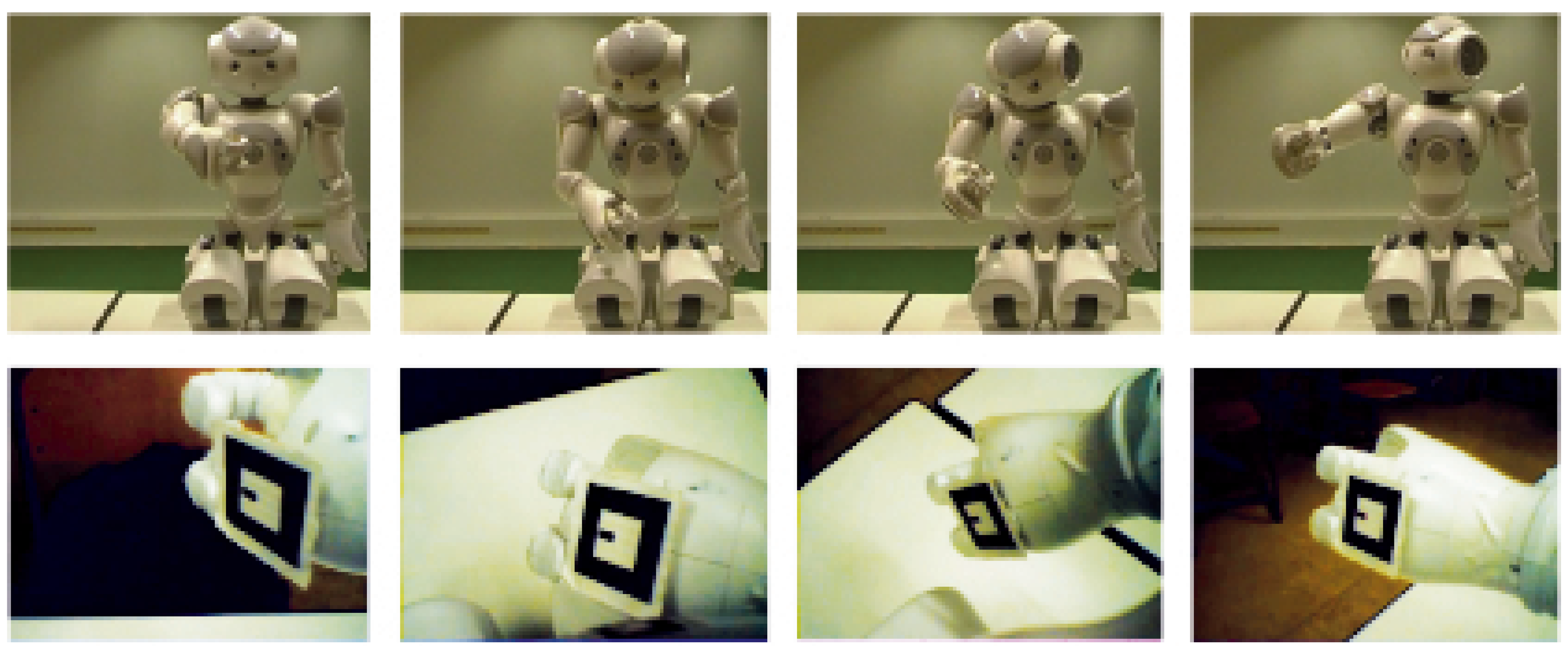

Figure 1: Random motor babbling sequence in a robot

## The Model

### Description

The model is inspired by **topographic maps** observed in the sensorimotor areas of the cortex. It consists of **two associated 2D SOMs** (Figure 2). Two different instances of a model were trained to simulate two different stages of skill development: the $5 \times 5$ **model** and the $15 \times 15$ **model**.

### Training

The training comprised of following steps:

1. Presentation of the 3D hand coordinates to the first SOM and 4D joint coordinates to the second SOM
2. Identification of **winning neurons** in both SOMs
3. Strengthening of **Hebbian connections** between the two winning neurons

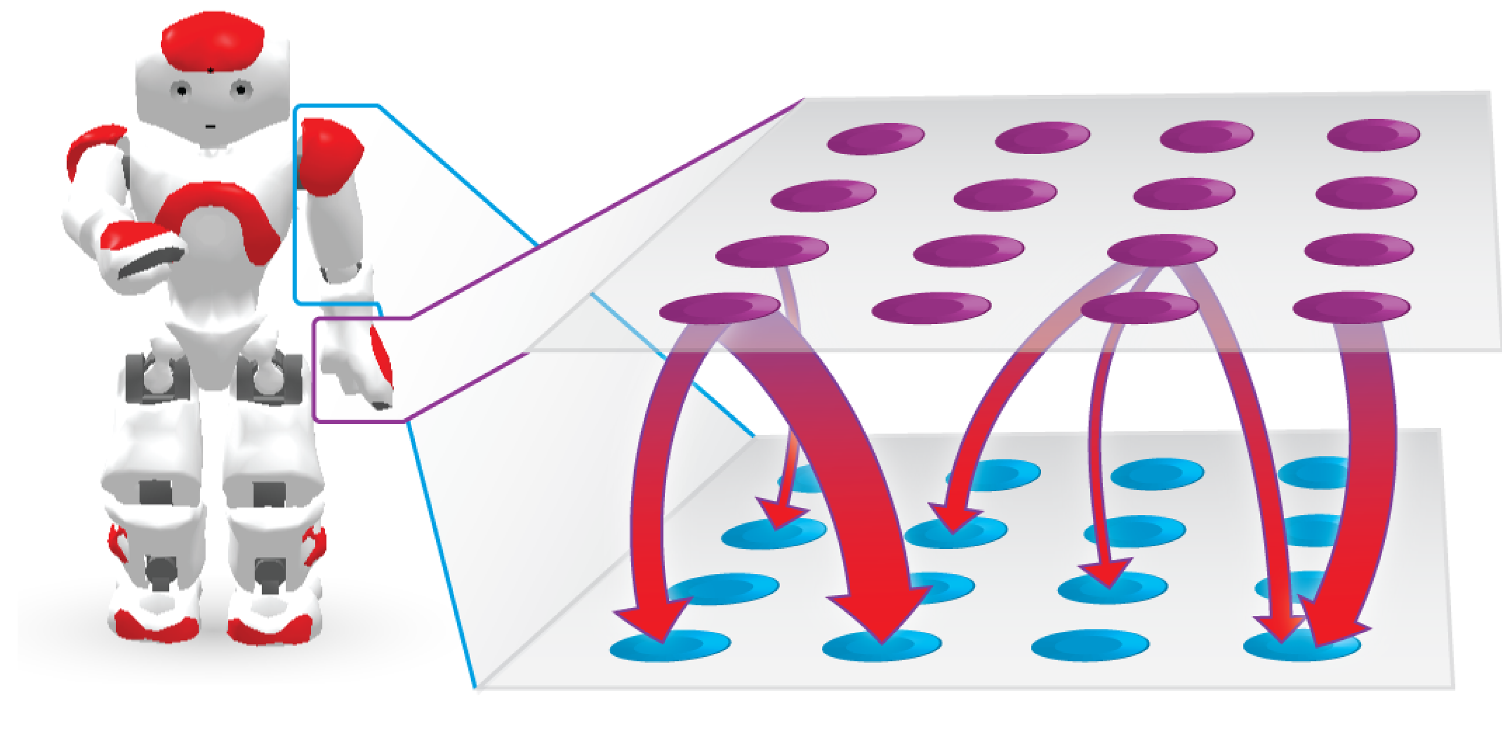

Figure 2: The SOM-based model

## The Experiment and Results

A human subject was holding and randomly moving an object tagged with a marker in front of the robot for approximately 2.5 minutes. The robot followed the object with its head and arm. The robot pointed to the object if it was presented out of its reach (Figure 4).

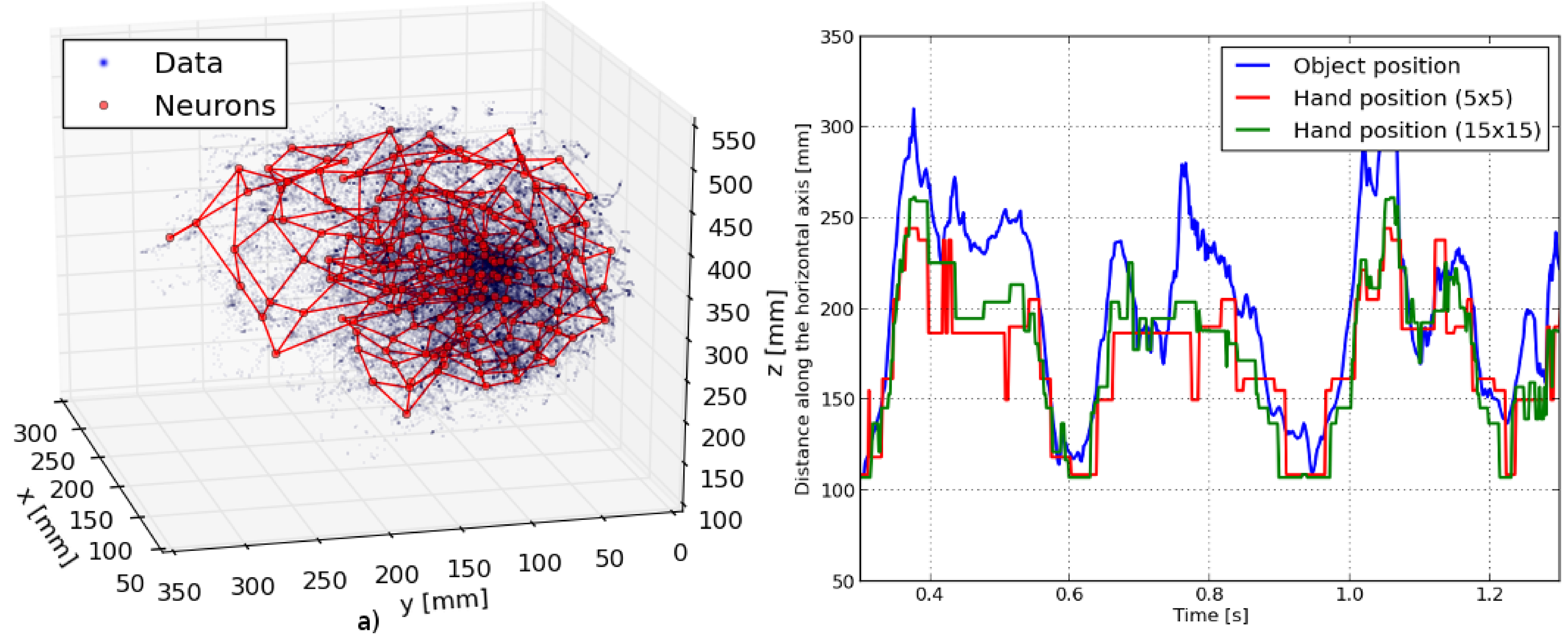


Figure 3: SOM with 225 neurons covering the left hand babbling trajectory (a), hand and object positions from the experiment (b)

Compared to the $5 \times 5$ model ($\mathrm{Mean\ error} = 99.93\mathrm{mm}$, $\mathrm{Std.\ Dev.} = 32.10$), there was a significant **improvement in pointing** accuracies for the $15 \times 15$ model ($\mathrm{Mean\ error} = 80.32\mathrm{mm}$, $\mathrm{Std.\ Dev.} = 33.41$), conditions; $t(1400) = 76.47, p < 0.05$.

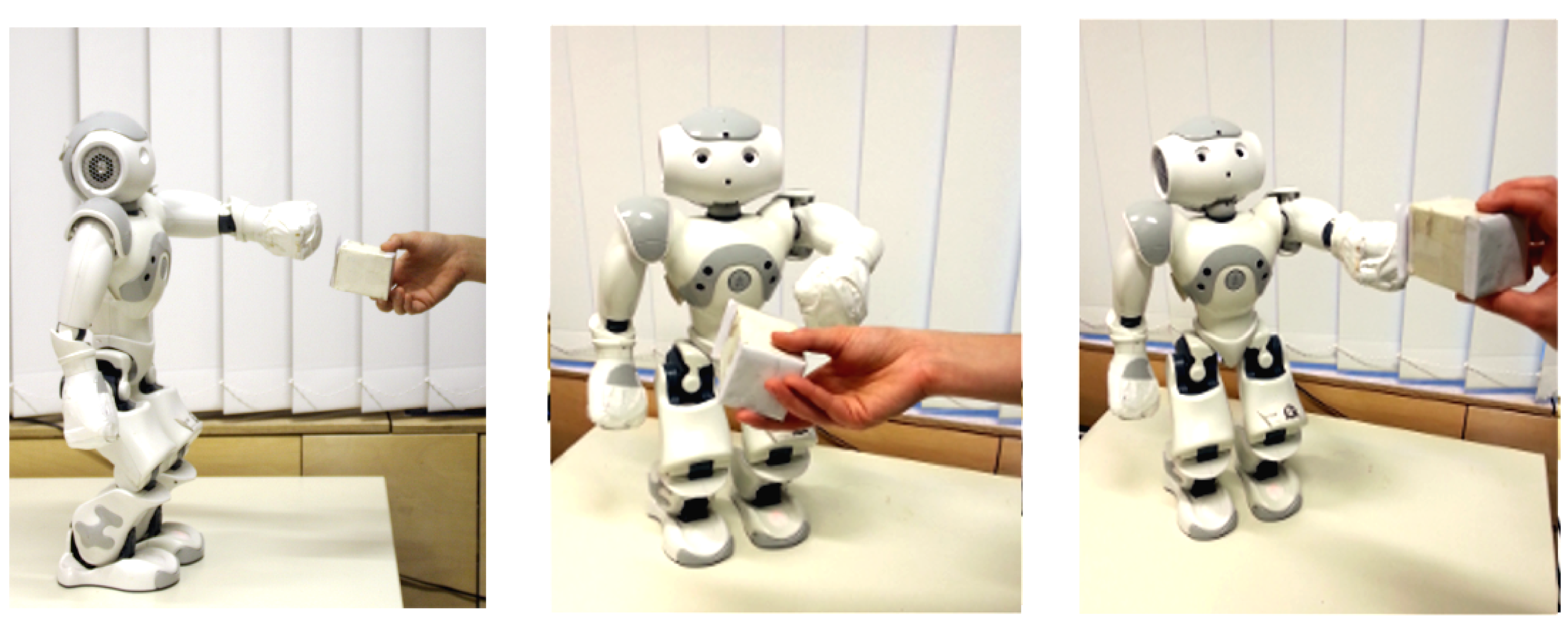

Figure 4: The experiment. The robot points to the tagged object

## Conclusion

The SOM-based model explains how pointing behavior emerges from sensorimotor learning of hand-eye coordination. The experiment demonstrates that a humanoid robot equipped with the model exhibits pointing through body babbling. An increase in the size of the SOMs improves the accuracy of pointing.

### Acknowledgments

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### References

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