Restricted Boltzmann Machine with Transformation Units in a Mirror Neuron System Architecture

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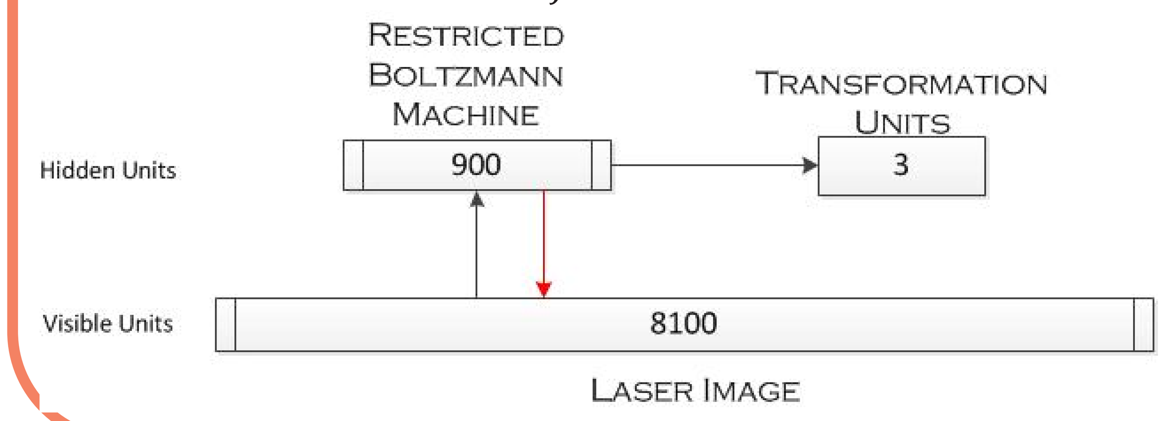
Contribution

1. Canonical neurons in ventral premotor area F5 are active when an object that can be grasped by movements is observed [1].
2. The relative position between an observer and an object should be considered in an integral mirror neuron system model [2].
3. This model emphasizes the representation of the relative position of the object. Specifically, this position information is represented in a distributed manner in units called transformation units.

RBM with Transformation Units

The RBM-TU is a modified version of the RBM. It has the same architecture as RBM except the full connections between transformation units and hidden layer. It can be regarded as a hybrid architecture consisting of a generative model and a discriminative model. The RBM represents and reconstructs the learned images, while the transformation units represent the relation between the objects and the sensor.



RBM Training

The weights between hidden units and visible units are updated in the same way as the generic RBM model by Contrastive Divergence [3]. Then the hidden units and the transformation units form an independent two-layer network, in which the weights are updated by back-propagating the error from the transformation units. The update rule of connection weights between transformation units and hidden units is

$$\Delta W_{h,i} = \eta \delta_i H_h \qquad (1)$$

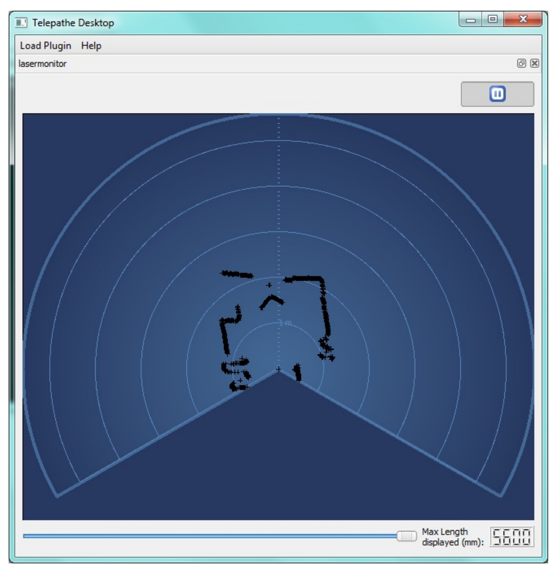
where η is the learning rate of transformation weights, δ is the output error for the transformation units, and H_h is the output value of the hth hidden unit, with sigmoid activation function. The target values of transformation units for back-propagation are set to be zero.
The full algorithm is as following,

- **Update RBM weights** Update the connection weights between the hidden units and the visible units using Contrastive Divergence.
- **Update transformation weights** Calculate the values of hidden units given the updated weights and input. Update the connection weights between the hidden units and the transformation units (Eq. 1).

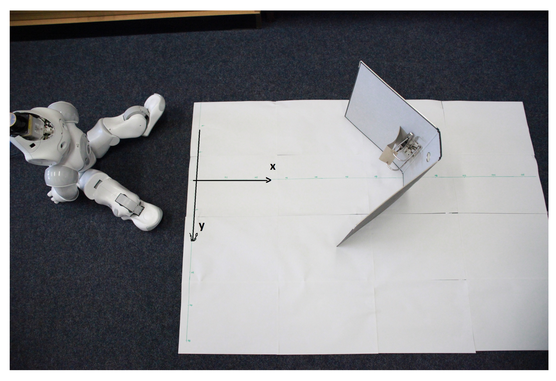
Experiment Setup

1. We attempt to model the tactile sensing via the laser sensor and use its information to represent the information of the object position, which is a more accurate position information compared to only using a vision system.
2. Our environment is a normal office and an object is placed in front of the NAO for training.
3. We used the range sensor to produce 500 images as data sets. The two-dimensional dotted images with small noise variance of the laser heads surrounding are captured.
4. As soon as the training is over, the same object is placed in different positions from the trained position as long as they can be scanned by the laser sensor.

a) Laser sensor in the NAO head



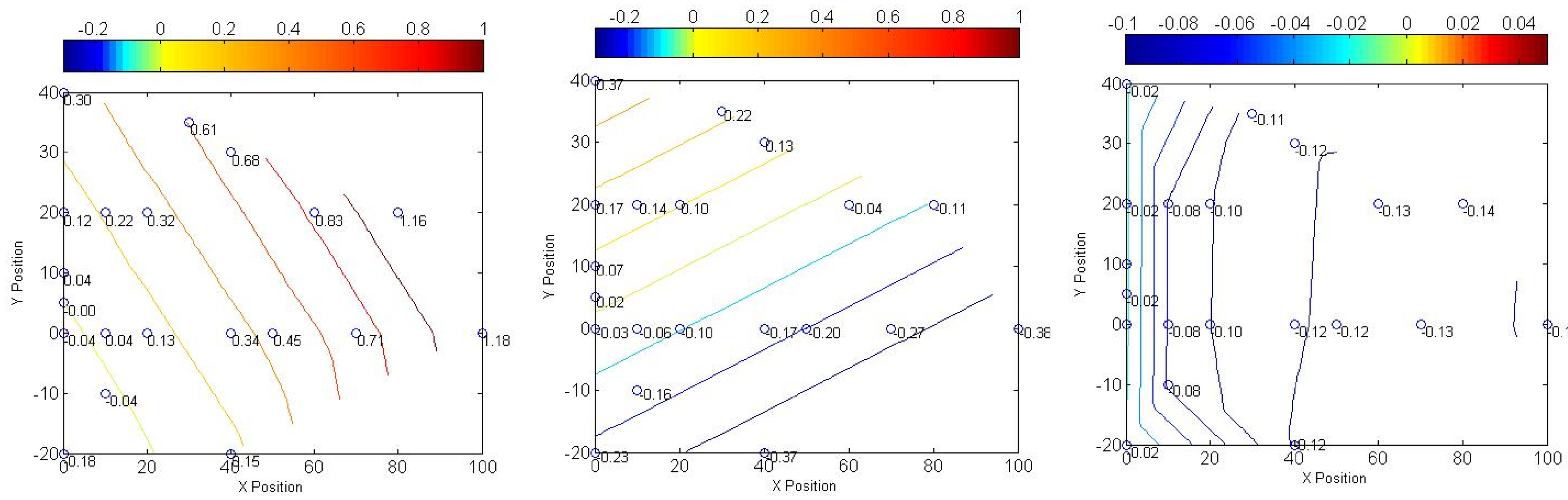
b) Image obtained from laser



c) Relation between NAO and object

Experimental Results

In the recognition mode, the connection weights are fixed and the values in the transformation units are calculated with laser images of different relative positions of the object. We compare the values in transformation units with the selected untrained relative positions. Interpolation is used to estimate the values in-between to better illustrate the transformation units. We can interpret this combination of the transformation units as the ability to locate a unique position of the object; in this way we can regard the transformation units as a representation of the relative positions between the robot and the object.



Relation between values in transformation units and positions

Conclusions

1. Restricted Boltzmann Machine with transformation units to model the functional model of observer-object relation representation in canonical neurons.
2. The training of the model is a combination of Constrastive Divergence and Back-propagation.

References

[1] Metta, G. et al. Understanding mirror neurons: a bio-robotic approach In *Interaction studies 2006*

[2] Oztop, E. and Arbib, M.A. Extending the mirror neuron system model, I In *Biological cybernetics 2007*

[3] Hinton, G. A practical guide to training restricted boltzmann machines In *Momentum 2010*

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