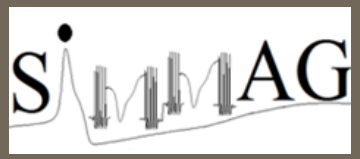
Implementation of Stimulus-Movement Matching Experiment on a Humanoid Robot



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(SIMMAG)

Workshop on Autonomous Cognitive Robotics 2014

Match a stimulus with an appropriate action

- Inspiration from temporal sequence task of Macaca Monkeys [1]
- Implementation of learning a reward predicting stimuli
- Dynamical System Approach to model Basal Ganglia-Thalamus-Cortex (BTC) Loop
- Temporal Difference Learning
- Associate a stimulus with an action & rearrange this association

[1] Tanji J. & Shima, K., 1994. Role For Supplementary Motor Area Cells in Planning Several Movements Ahead. Nature 371, 413-416.

Motivation

- Using a mobile computer to investigate the BTC model's compatibility to a dynamic environment.
- As a first step, to show that the model due to learning can manage to match the stimulus with different actions online.
- To prepare a suitable platform to test the computational neuroscience models for high level tasks.

Darwin-Op and Environment

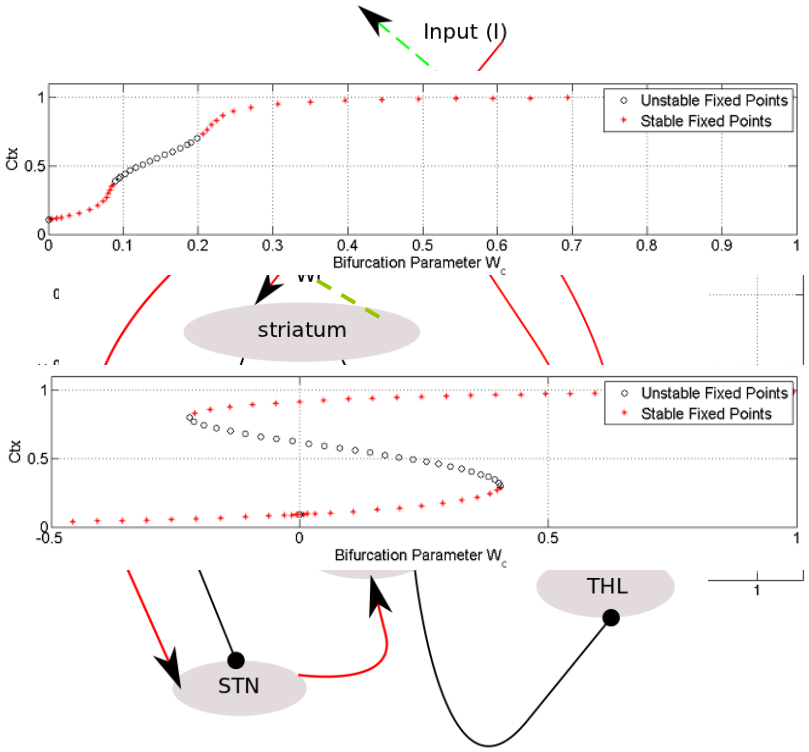
- Open Platform
- C++
- Intel Atom 1.6 GHz
- Mobile
- Vision Processing
  - Colour Detection
- Colour Cards (R-Y-B-G)
- Predefined actions

Car

20 servo motors

BTC: Dynamical System Model & Temporal Difference Learning

Bifurcation parameters: Wc & Wr



BTC Model Equations

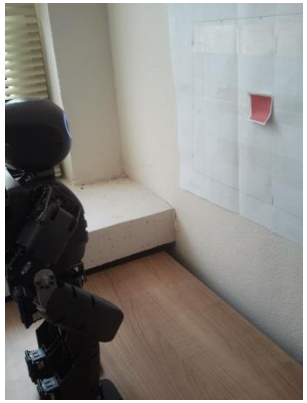
$$S(k) = WcI(k)$$
$$Ctx(k+1) = f(\lambda Ctx(k) + Thl(k) + S(k))$$
$$Str(k+1) = Wrf\big(Ctx(k)\big)$$
$$GPe(k+1) = f(-Str(k))$$
$$Stn(k+1) = f(Ctx(k) - GPe(k))$$
$$GPi(k+1) = f(Stn(k) - Str(k))$$
$$Thl(k+1) = f(Ctx(k) - GPi(k))$$

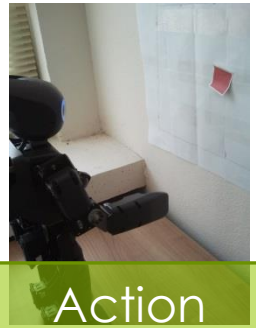
Temporal Difference Learning Rules

$$V(k) = Wv(k)I(k)$$
$$\delta c(k) = r_c + \mu V(k-1) - V(k)$$
$$Wv(k+1) = Wv(k) + \eta_c \delta c(k) I(k)$$
$$Wc(k+1) = Wc(k) + \eta_c \delta c(k) Ctx(k) I(k)$$
$$Wr(k+1) = Wr(k) + \eta_c \delta c(k) Ctx(k) Str(k)$$

Denizdurduran, B.,
http://www.simmag.itu.edu.tr/yayinlar/denizdurduran_Msc_Thesis.pdf

Link between action and stimulus





Input

BTC Model

Result

Action Decision (or randomly)

Robot is shown a colour card (R-Y-B)

Changes behaviour of dynamical system

TDL Rules

reward

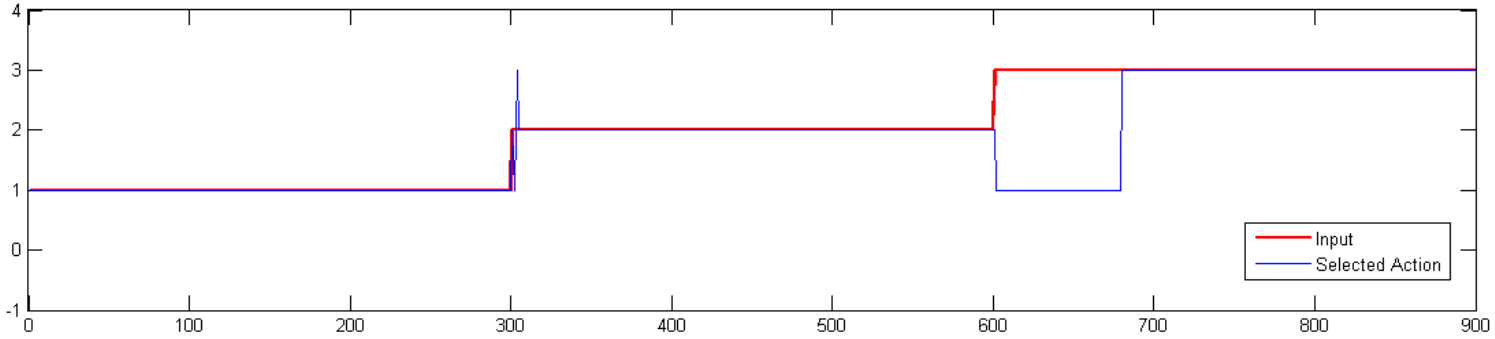
Robot is shown green card

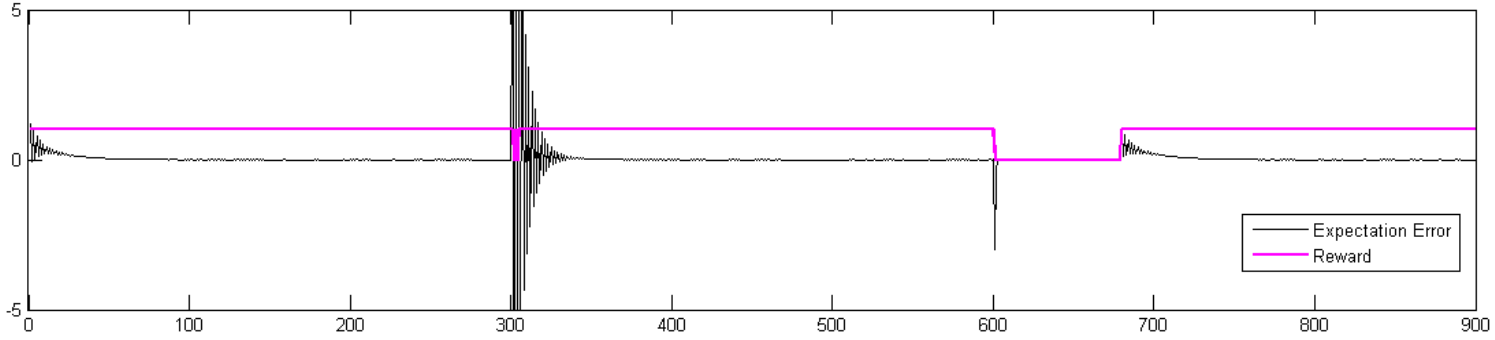
- Learns to match an action with a stimulus
- After learning, giving no reward to already matched action urges to rearrange the association built between stimulus and action

MATLAB-First Maching

1st action ⇔ 1st stimulus
2nd action ⇔ 2nd stimulus
3rd action ⇔ 3rd stimulus

$$Wc=\begin{bmatrix} 8.68 & 8.11 & -0.56 \\ 0.11 & 23.14 & 2.55 \\ 0.11 & 7.5 & 9.14 \end{bmatrix} \quad Wr1=\begin{bmatrix} 0.8275 \\ 0.9986 \\ 1 \end{bmatrix} \quad Wr2=\begin{bmatrix} 1 \\ 0.6466 \\ 1 \end{bmatrix} \quad Wr3=\begin{bmatrix} 0.9108 \\ 0.9098 \\ -0.0556 \end{bmatrix}$$

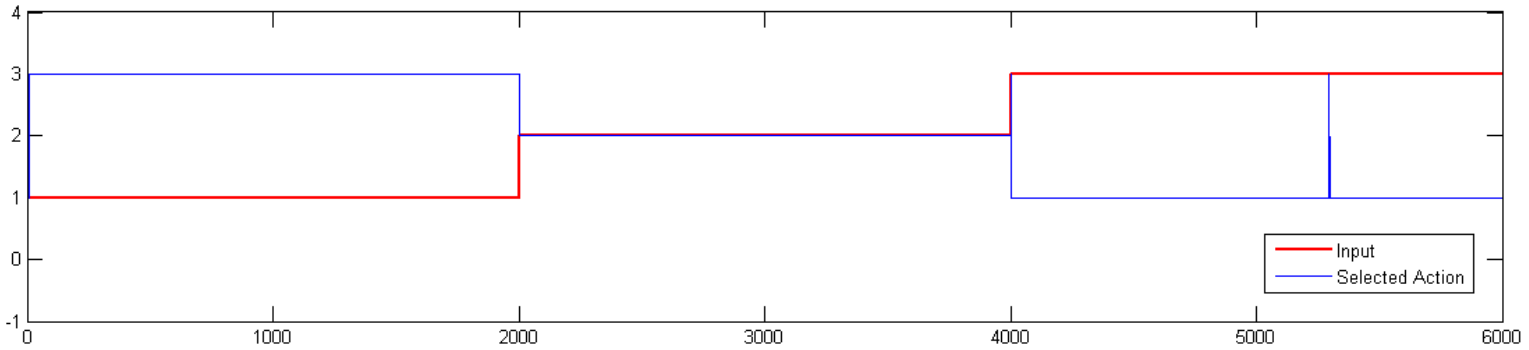


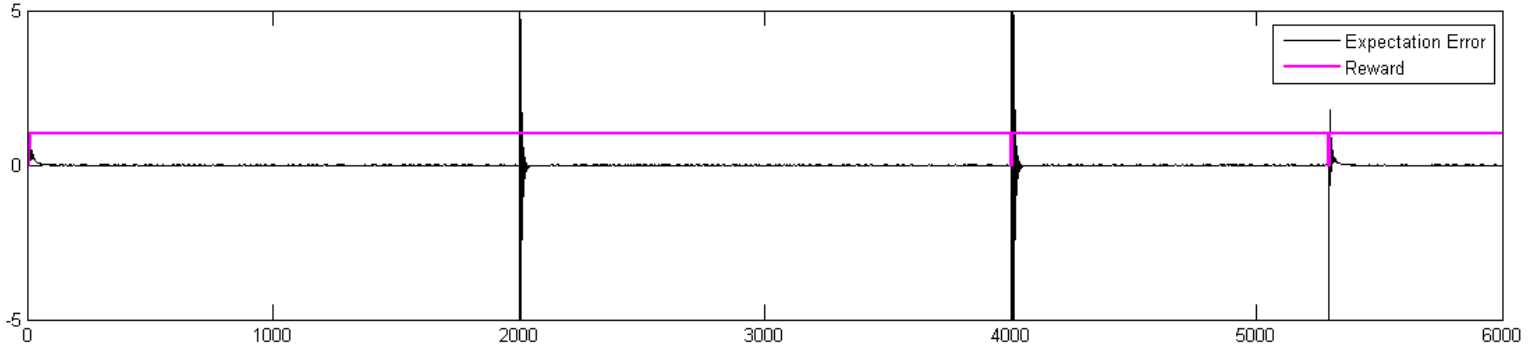


Matlab-Rearrange First Matching

1st action ⇔ 3rd stimulus
2nd action ⇔ 2nd stimulus
3rd action ⇔ 1st stimulus

$$Wc=\begin{bmatrix} 3.06 & 8.11 & 6.38 \\ 1.19 & 1.88 & 11.6 \\ 0.3 & 7.51 & 18.6 \end{bmatrix} \quad Wr1=\begin{bmatrix} 1 \\ 1 \\ 0.5497 \end{bmatrix} \quad Wr2=\begin{bmatrix} 1 \\ 0.5167 \\ 1 \end{bmatrix} \quad Wr3=\begin{bmatrix} 0.5498 \\ 1 \\ 1 \end{bmatrix}$$



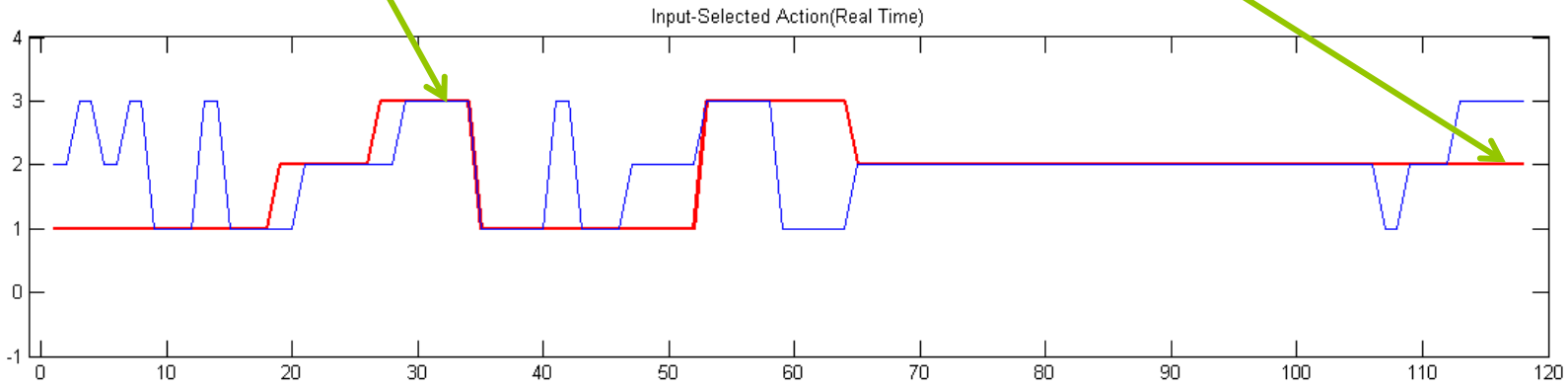


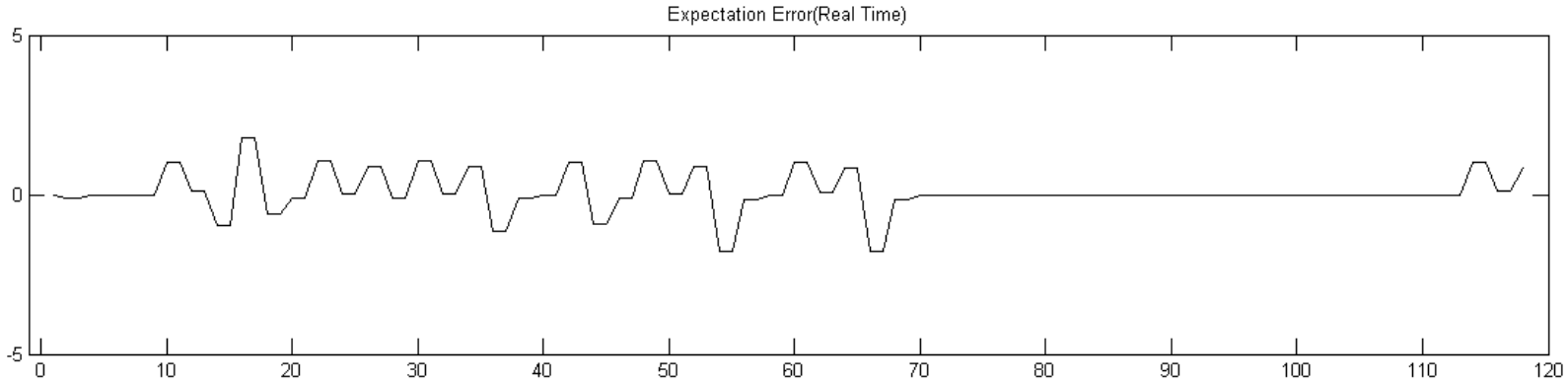
Results

In Real Time

$$Wc_{first}=\begin{bmatrix} 2.2 & 0.05 & 0.18 \\ 0.09 & 1.97 & 0.03 \\ -0.77 & 0.18 & 1.96 \end{bmatrix}$$

$$Wc_{second}=\begin{bmatrix} 0.15 & 0.05 & 1.91 \\ 1.87 & 0.17 & 0.03 \\ 0.14 & 1.9 & 0.17 \end{bmatrix}$$





Video

Conclusion

- A dynamical system model of BTC loop with learning has been realized on a humanoid robot in real time successfully.
- The dynamical system is forced to converge to a specific fixed point through learning. The learning is accomplished by modifing the bifurcation parameters.
- The more an action is reinforced, it is harder to suppress the learnt connection
- After showing the compatibility of the model and robot, the SNN model and pattern recognation module can be implemented.

References

- [1] Tanji J. & Shima, K., 1994. Role For Supplementary Motor Area Cells in Planning Several Movements Ahead. Nature 371, 413-416.
- [2] Denizdurduran B., Sengor N.S., 2012. A Realization of Goal-Directed Behavior-Implementing a Robot Model Based on Cortico-Striato-Thalamic Circuits. ICAART 2012, Algarve, Portugal.
- [3] Prescott, T. J., Montes-Gonzalez, F. M., Gurney, K., Humpries, M. D., Redgrave, P., 2006. A Robot Model of the Basal Ganglia: Behaviour and Intrinsic Processing. Neural Networks, 1-31.

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Questions?

Thank you…

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