Robot's behavior driven by internal tensions regulated by pulsed para-neural networks

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Abstract We tested a psychodynamic controller called PreBrain using a simulated mobile robot. According to our approach, an agent seeks for pleasure that comes from the discharge of selected psychic tensions. The quality of control depends on the pleasure record. Perception may regulate the dynamics of tensions. The discussed version of PreBrain processes three pleasure-related tensions: boredom, interest, and excitement. An object-of-interest appearance discharges the first tension, but results in an increase of the second one. Contact between a toy and the robot's frontal touch sensor discharges tension related to excitement.

There are two kinds of building elements used for PreBrains: tension-accumulation cells (TAC) and pulsed para-neural networks (PPNN). TAC produces spiketrains whose frequency depend on accumulated tension, where increment/decrement of tension levels depend on received spiketrains and spontaneous accumulation or discharge. PPNN is a graph consisting of processing nodes and directed edges representing defined delays.

We tested three kinds of PreBrains. The first one forced the robot to rotate to get an image of an object-of-interest (toy) to the central zone of the visual field and then to go forward full-speed. The second one slowed the appropriate wheel to facilitate a turn when the image of the toy deviated from the center of the visual field. The third one employed a mechanism detecting certain cases of disappearance of the object from visual field and facilitating appropriately fast turn.

1 Introduction

The psychodynamic approach to machine intelligence assumes that an agent is doing something because he seeks for pleasure, where pleasure is nothing but a possibly fast discharge of a psychic tension [1]. Such relationship between tension and pleasure was suggested by Sigmund Freud [2][3]. Although not all Freudian concepts are supported by convincing empirical evidence, some of them seems to be valuable tips for building artificial minds. One of such concepts is continuous battle between conflicting mental forces [4] that, when implemented, resulted in robot's life-like hesitation [5][6].

PreBrain is a simple controller employing basic psychodynamic mechanisms intended to evolve toward a complex neural-like circuitry in which an emergence of communication behaviors and the phenomenon of thinking could take place [7][8]. PreBrain has a highly modular structure. One kind of modules, called tension-accumulation cells (TAC) constitute Tension Accumulator. The second kind of modules, called pulsed para-neural networks (PPNN) constitute Tension Discharger. There is a bi-directional communication between Tension Accumulator and Tension Discharger (Fig. 1). Since not only perception contributes to increase of tension level, PreBrain's "mental life" (resulting in various actions) can take place outside the framework of sensing-action loop.

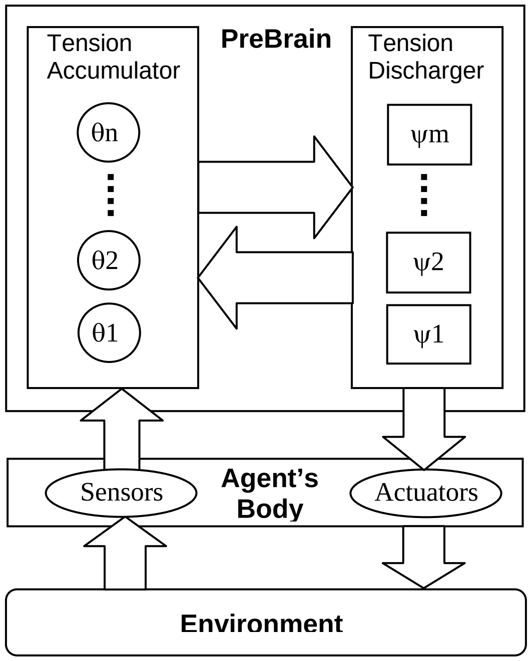


Fig.1. PreBrain structure and its relationship with agent's body and environment. θ1, θ2, …, θn – tension-accumulating cells (TAC); ψ1, ψ1, …, ψm – pulsed para-neural networks.

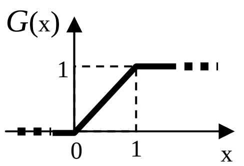
The PreBrain research contributing to both the Artificial Brain project conducted at the ATR, Kyoto and Intelligent Controller based on Artificial Brain (IC/AB) conducted at the USTB, Beijing [9]. Currently investigated PreBrains still fit to the behavior-based paradigm summarized by Ronald Arkin as sharing an aversion to the use of representational knowledge, emphasis on a tight coupling between sensing and action, and decomposition into behavioral units [10, p. 173]. Rodney Brooks's postulate to reject "cognitive box" [11, p. 36] is treated in PreBrain research only as a ban on handcrafted algorithms manipulating handcrafted symbolic knowledge. Intended development of psychodynamic architecture assumes facilitating emergence of various models of reality (perceived and imagined) [12], which will require a kind of knowledge representation to emerge as a result of social interactions.

2 PreBrain cells

The primary cause for any PreBrain action (related to environment or to itself) is a psychic tension being accumulated in one or more TACs. PPNN is a complementary technique used for purposeful manipulation on spiketrains, which is difficult in the framework of TAC-only networks. Although internal states of TAC are real numbers, whereas internal states of PPNN cells are integers, all of the cells send/receive only spiketrains, i.e. series of pulses of unitary amplitude occurring at discrete moments of time called clocks.

TAC state changes according to the formula:

$$\theta_{t+1} = G\left(\theta_t + \frac{\frac{u}{T_S} + \frac{A_t}{T_A} - \frac{D_t}{T_D}}{f}\right)$$



where
t – time (in clocks),
θ_t – accumulated tension,
u – parameter determining direction of uncontrolled change of tension (1 – increase, -1 – decrease),
$A_t = A_{0,t} + A_{1,t} + \ldots + A_{15,t}$ – tension-increasing signal,
$D_t = D_{0,t} + D_{1,t} + \ldots + D_{15,t}$ – tension-discharging signal,
T_S – uncontrolled increase/discharge time,
T_A – duration of tension change from 0 to 1 when influence of uncontrolled charge/discharge is negligible and the control signal A_t is a spiketrain of 1s only,
T_D – duration of tension change from 1 to 0 when influence of uncontrolled charge/discharge is negligible and the control signal A_t is a spiketrain of 1s only,
f – frequency of clocking (clocks per second).

TAC produces an output spiketrain whose frequency is proportional to current tension level so $f_t^{out} \approx k\, f\, \theta_t$, where $k \in [0;\ 1]$ is a parameter regulating the tension impact. According to psychodynamic assumptions, pleasure is related to the dynamics of tension discharge. The greater tension discharged in a given time, the greater pleasure recorded; the faster discharge of a given tension, the greater pleasure recorded.

PPNN is a graph consisting of processing nodes and directed edges, called axons. The nodes represent functions operating on spiketrains. Axons represent pure delays [13]. To date we used PPNNs in which a given node can be a *mexor* or *paraneuron*. Mexor returns a spike at clock *t* if it received one and only one pulse at clock *t-1*. Paraneuron returns a pulse and resets its counter at clock *t* if the counter was greater than 1 at clock *t-1*, while counter at clock *t-1* is counter at clock *t-2* plus the weighted sum of pulses the cell received at clock *t-2* (a weight can equal 1 or –1). If axons are strings of one-input mexors and every cell is a 1×1×1 cube whose coordinates are three integers, then such a PPNN is called NeuroMaze. We have developed the NeuroMaze editor/simulator for rapid prototyping of desired PPNNs [14]. It was shown that a PPNN/NeuroMaze can be build for every Boolean function and practically for every manipulation on spiketrains [15].

3 How PreBrain works

Figure 2 shows PreBrain that was a subject to the presented research. The attached mobile robot uses two motors equipped with 2-input frequency-to-voltage converters (FVC). A frequency provided to the left FVC's "positive input" (L+) or the FVC's "negative input" (L-) forces the left wheel to roll forward or backward, respectively. The same applies to the right FVC's inputs (R+ and R-). Hence, equal-frequency spiketrains provided to L+ and R+ results in the robot's moving forward, whereas unequal spiketrains provided to L+ and R- results in the robot's rotation. Spiketrains to FVCs are provided by PPNN labeled Or8x4 (four 8-input OR-gates). The TAC labeled θ0 is related to boredom. Its T_S = 10s and u = +1. Its output is connected to the central input of the PPNN labeled PB1. Tension θ0 grows by internal causes and PB1 facilitates discharging via forcing the robot to wander in search for something interesting (spiketrains provided to L+ and R+). When the PreBrain is switched on, we observe the robot start, 1 accelerate for 10s, and then proceed forward at full-speed. Note that this behavior is not caused by any perception.

Although, according to psychodynamic approach, perception does not cause behaviors, it can regulate them. If right or left touch sensor is excited, PB1 (responsible also for obstacle avoidance) redirects one of involved spiketrains (L+ to L- or R+ to R-), which results in robot's rotation. A device labeled V-Green5 processes images from camera and recognizes an object-of-interest (and its direction) and provides signal D_t to θ0 where T_D = 0.1s. Hence, when an object-of-interest is seen, the robot immediately ceases moving.

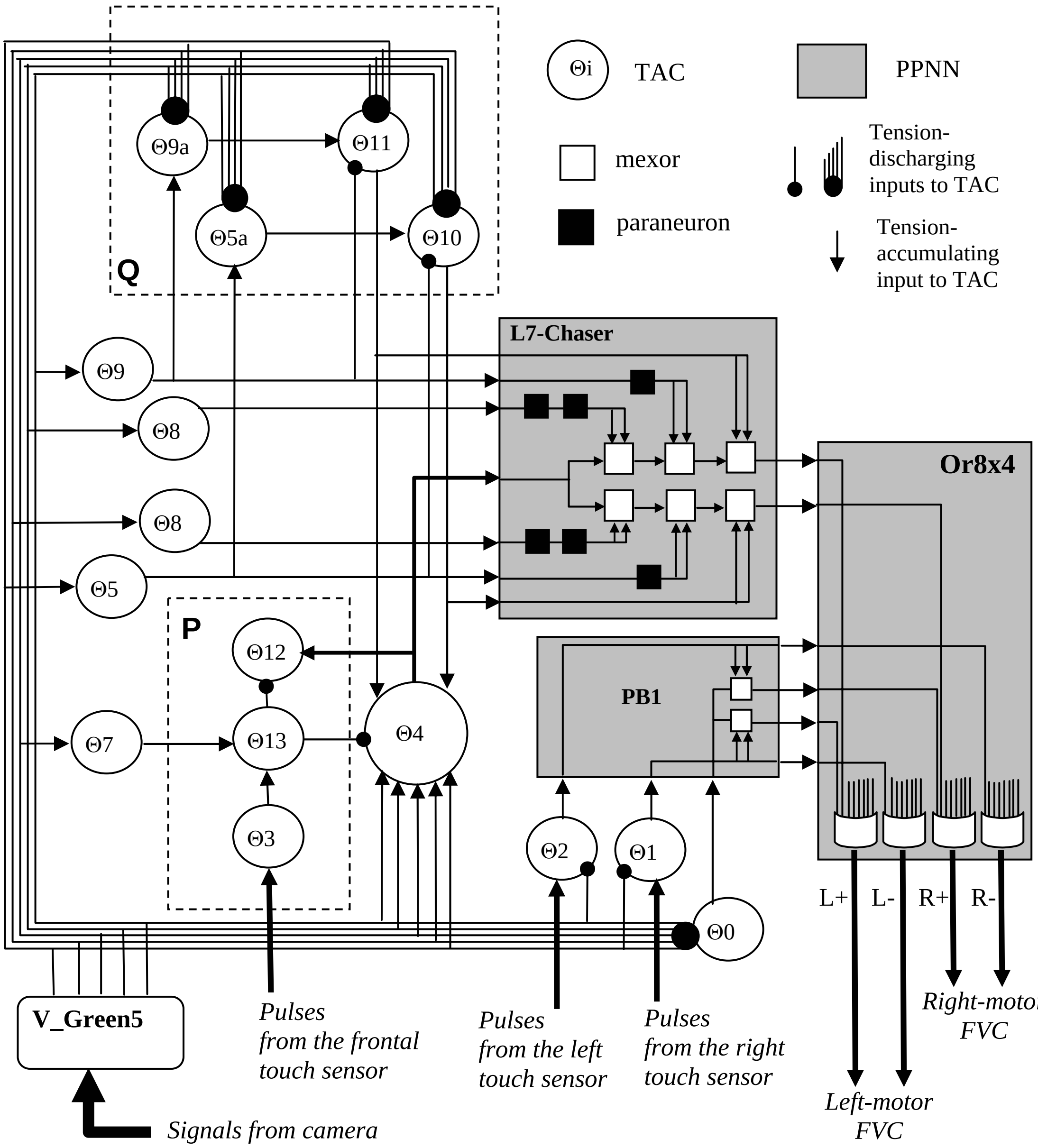


Fig.2. An example of PreBrain. TAC – Tension-Accumulating Cell; PPNN – pulsed para-neural network. **V_Green5** – a device processing signals from camera, recognizing object of interest and determining the direction it is seen at (one of five considered). *FVC* – Frequency-to-Voltage Converter. L+, L- – positive and negative input to left-motor FVC; R+, R- – positive and negative input to left-motor FVC (equal-frequency spiketrains provided to L+ and R+ results in the robot's moving forward; spiketrains provided to L+ and R- results in the robot's rotation). **Or8x4** – PPNN substituting four 8-input OR-functions. Θ0 – tension related to "boredom"; Θ1, Θ2 – tensions resulting from touching an obstacle (disabled in case of touching an object-of-interest). **P** – "pleasure" block: Θ3 – tension resulting from stimulation of the frontal touch sensor; if an object-of- interest is being touched and seen in the middle of visual field (Θ3 & Θ7), the tension Θ12 (representing "excitement") gets discharged contributing substantially to the "pleasure record". **PB1** – a PPNN providing signal from Θ5, Θ6 and Θ8...Θ11 to L+ and R+ (via Or8x4) and responsible for collision avoidance (blocking the spiketrain directed to L+ or R+ and providing a spiketrain to L- or R-, respectively, which result in robot's rotation); Θ4 – tension related to action-driving "interest" in a perceived object; it makes the robot going forward (in the course of providing spiketrains to L+ and R+ via Chaser and Or8x4) as well as increase of Θ12 at **P**. Θ5…Θ9 – tensions related to five directions an obiect can be seen at. **L7-Chaser** – a device providing a spiketrain from Θ4 to both L+ and R+ (via Or8x4) and allowing spiketrains from Θ5, Θ6 and Θ8...Θ11 to lower the frequency of the spiketrain provided to L+ or R+, which results in appropriate distortion of the robot's trajectory facilitating approaching the object-of-interest. **Q** – a device improving efficiency of the Chaser; it detects disappearance an the object of interest seen for the last time in the furthest left or furthest right zone of the visual field and in such case provides a dense spiketrain to appropriate inputs of the Chaser, which results in complete blocking of one of the Chaser's outputs, which results in providing a spiketrain to only one wheel, which results in a quick turn of the robot giving the object a chance to get back to the visual field.

If PreBrain consisted of θ0 and PB1 only, the robot would stay until the object's disappearance. But other tensions are also involved. θ4, representing "interest" (u = -1; T_S = 0.06s; T_A = 0.05s; T_D = 0.1s) gets high when the toy is detected and sends a spiketrain to the central input of L7-Chaser—a PPNN in which the axon carrying the spiketrain from θ4 forks into two branches delivering the spiketrain to both L+ and L- via Or8x4. Spiketrains leaving the Chaser will remain equal only when the toy is seen in the central zone of the visual field. Depending on how far the object deviates from the middle of the visual field more or fewer spikes are cut off the spiketrain passing through a given branch. In this way perceptual signals provided to other inputs of the Chaser regulate chasing behavior. If the object is out of current direction, frequencies of spiketrains provided to L+ and R+ differ, so the robot's trajectory becomes a circle of bigger or smaller radius.

Tension θ4 (to be interpreted as interest) is discharged when at the same time the object of interest is seen in the middle of the visual field (θ7) and being touched by the robot's frontal touch sensor. Necessary Boolean function is implemented as TAC θ13 "&". Related parameters are set so that discharging of θ12 ("excitement") contribute the most to PreBrain's "pleasure record". From the point of view of the "pleasure record", the best control strategy is to chase the toy, but not hurry with touching it.

4 Experiment

PreBrains were implemented using the ParallelBrain v.1.1 – a special client-server platform dedicated to rapid prototyping of very large modular brain-like structures. PreBrain clients were built partially as C++ programs and partially as pulsed para-neural networks (PPNN) synthesized using the NeuroMaze v. 3.0 Pro.

We tested three kinds of PreBrains. The first one used L6-Chaser that forced the robot to rotate to get a perceived image of the object-of-interest in the central zone of the visual field and then go forward full-speed. Such strategy of chasing appeared suitable for approaching motionless object. PreBrain of the second kind employed L7-Chaser, described in the previous section, which slowed down appropriate wheel when the image of the object deviated from the center of the visual field. Such strategy worked in case of chasing objects going with constant speed along straight lines. The third kind of PreBrain employed L7-Chaser together with a structure (labeled Q in Fig. 2) detecting disappearance of the object of interest seen for the last time in the furthest left or furthest right zone of the visual field and then providing a dense spiketrain to the highest or lowest input of L7-Chaser. This results in complete blocking of one of the Chaser's branches, which results in providing a spiketrain to only one wheel, which results in a quick turn giving the object a chance of getting again to the visual field.

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