Idea of memristor based computer

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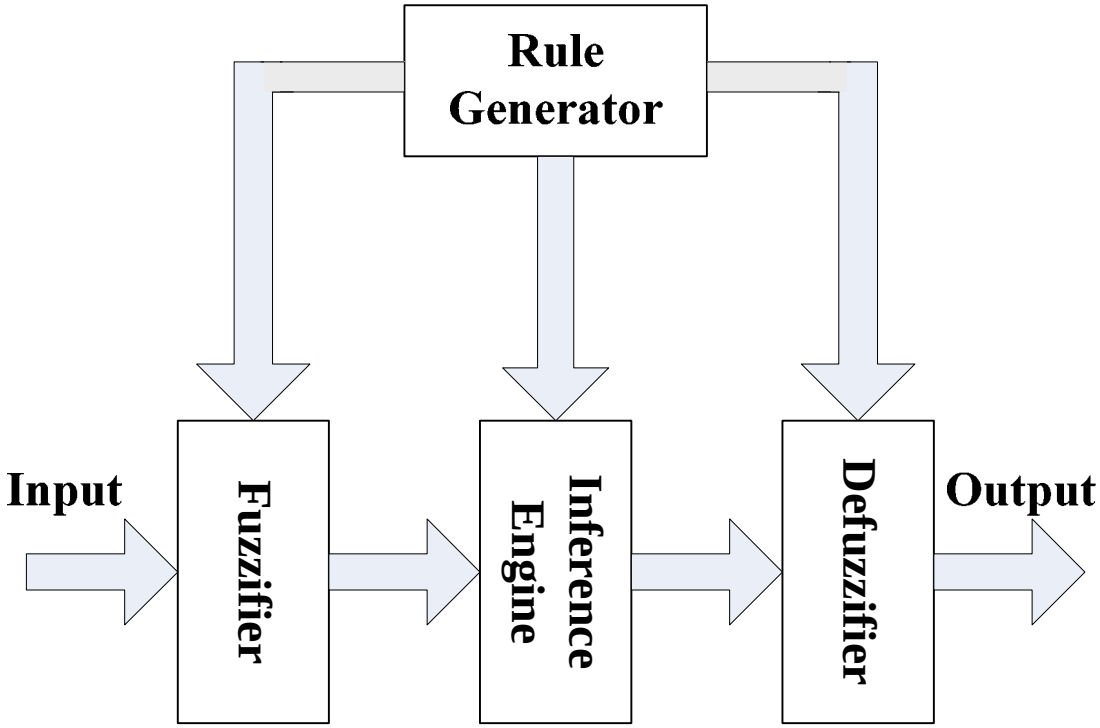
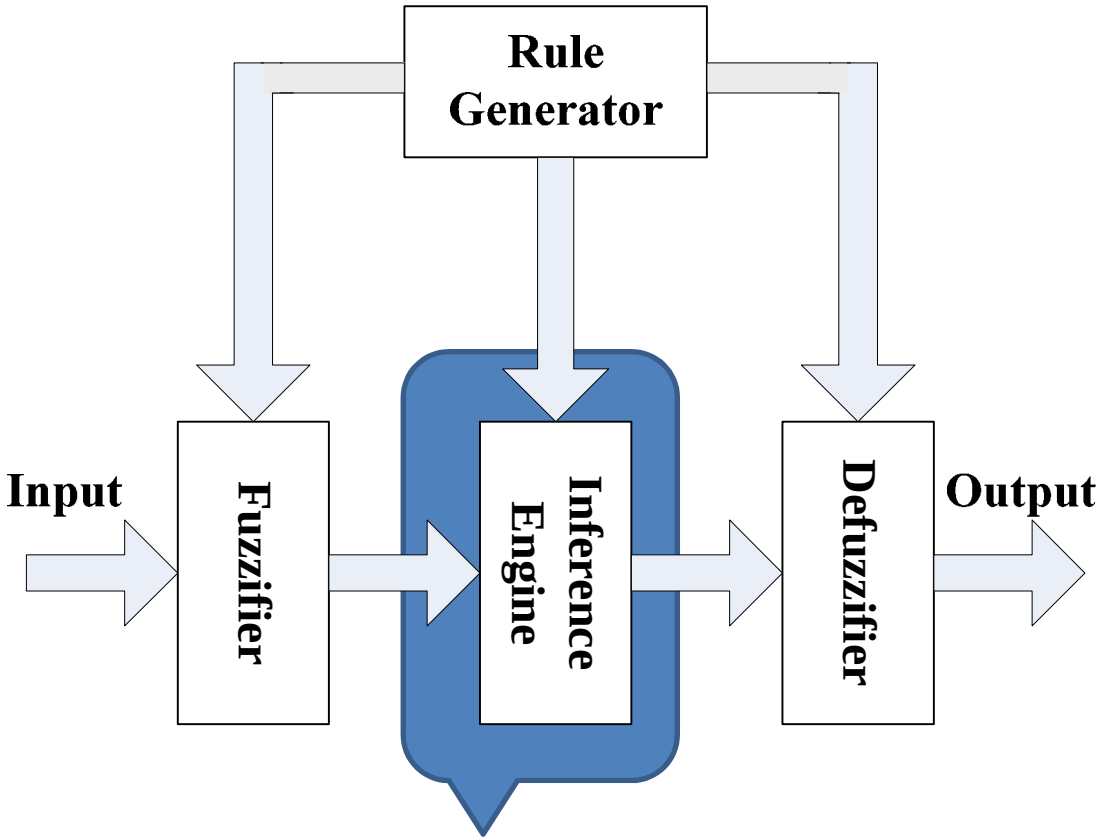
FSTA 2012 **Liptovský Ján**

Fuzzy Logic System



Fuzzy Logic System



fuzzy logic circuit
based on memristors

Memory Resistor - Memristor

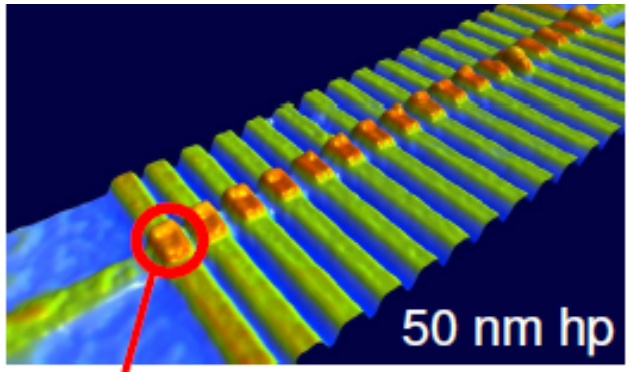
2011 –Leon Chua:
All **2-terminal non-volatile memory devices based on resistance switching** are **memristors**, *regardless of device material and physical operating characteristics*

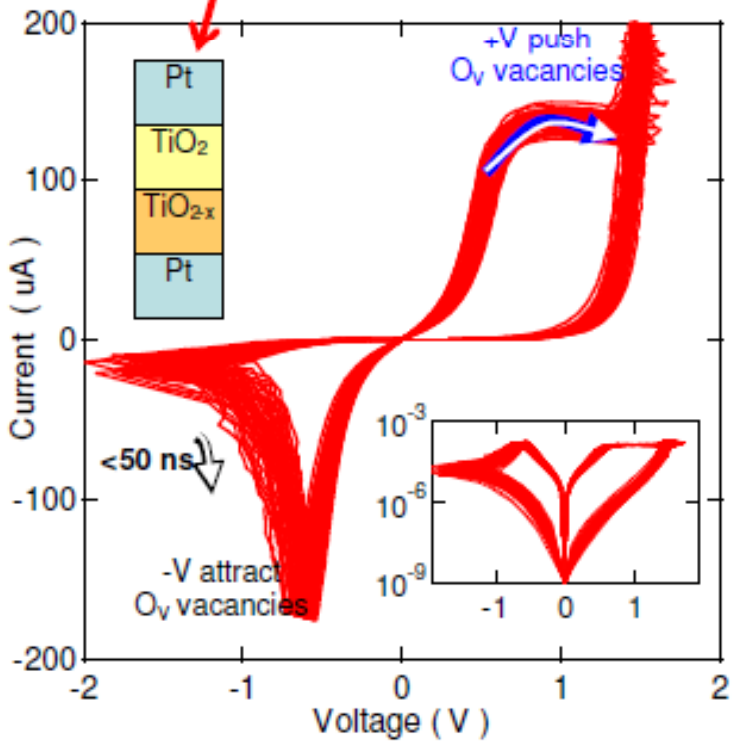
1960 – Bernard Widrow, Ted Hoff (ADALINE neural network)
1971 – Leon Chua (fourth fundamental circuit element)
2008 – HP Labs (memristive effect in TiO_2→ Chua´s memristor)

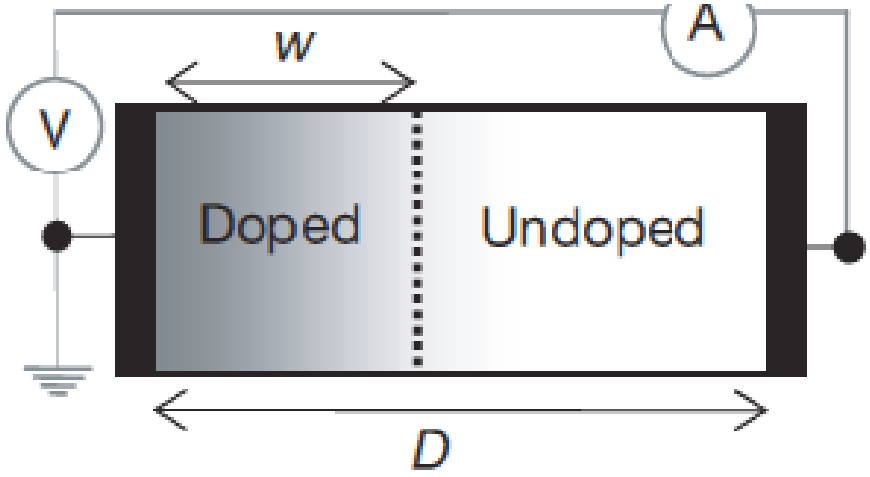
nature Vol 453|1 May 2008|doi:10.1038/nature06932

The missing memristor found

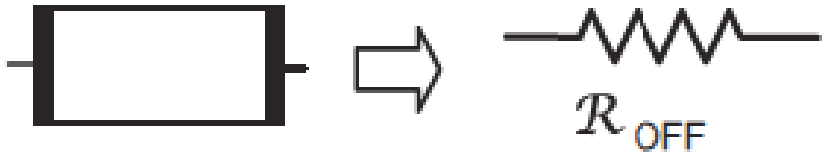
Dmitri B. Strukov[1], Gregory S. Snider[1], Duncan R. Stewart[1] & R. Stanley Williams[1]







Undoped:



Doped:

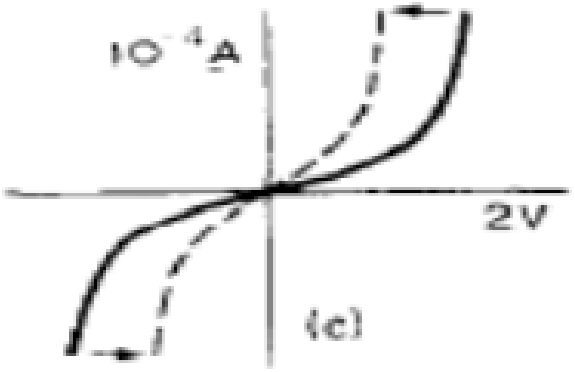
Solid-State Electronics Pergamon Press 1968. Vol. 11, pp. 535–541. Printed in Great Britain

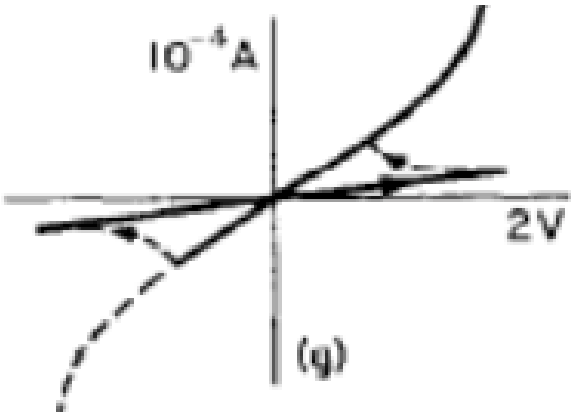
SWITCHING PHENOMENA IN TITANIUM OXIDE THIN FILMS

F. ARGALL

Physics Department, Chelsea College of Science and Technology, University of London, London, S.W.3

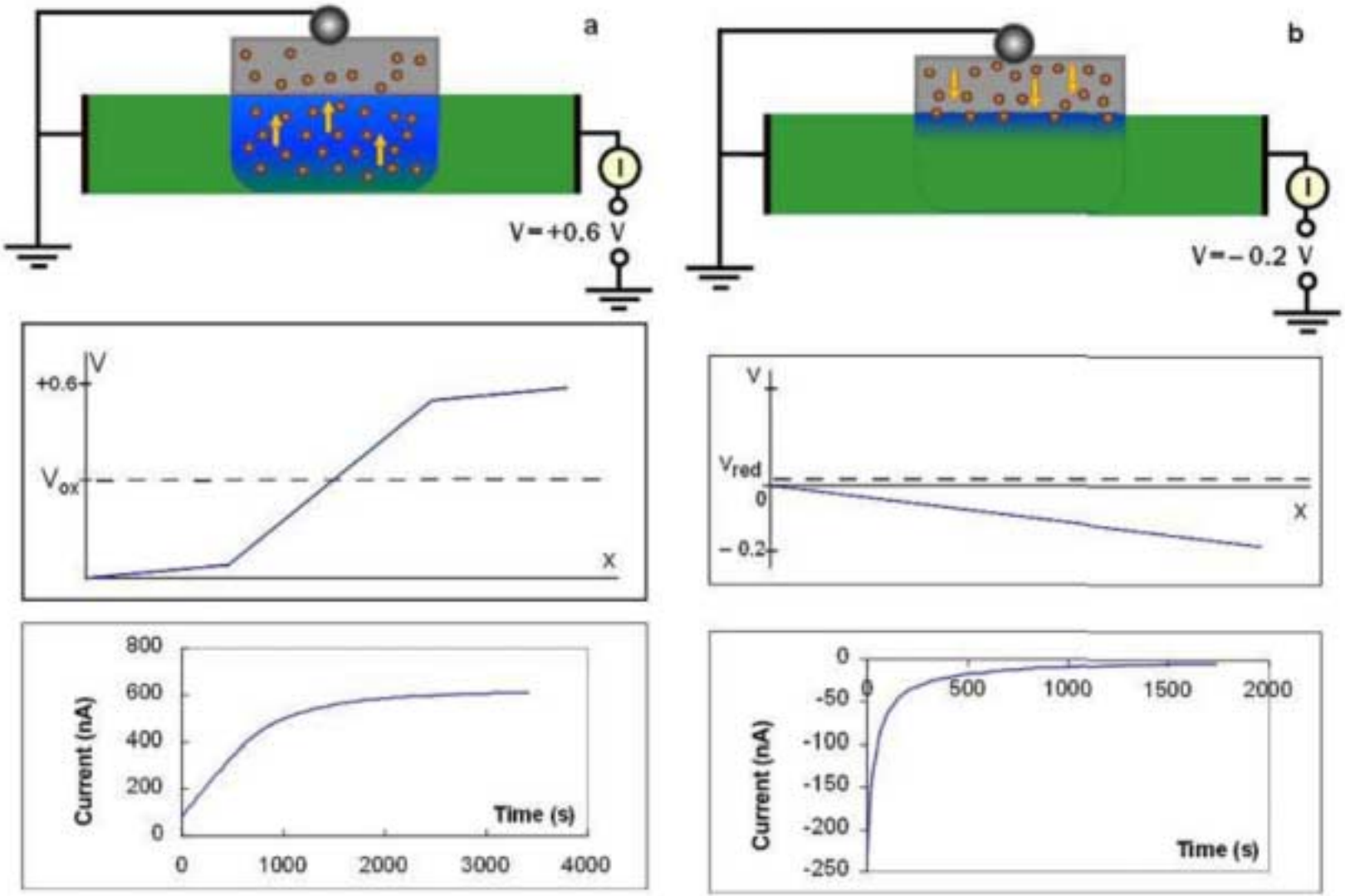
(*Received* 27 *July* 1967)





Electrochemically controlled polymeric device: a memristor (and more) found two years ago Victor Erokhin[1,2] & M.P. Fontana[1]

2008



Ø.G. Martinsen[1,2], S. Grimnes[1,2], C.A. Lütken[1] and G.K. Johnsen[1]

Memristance in human skin

2010

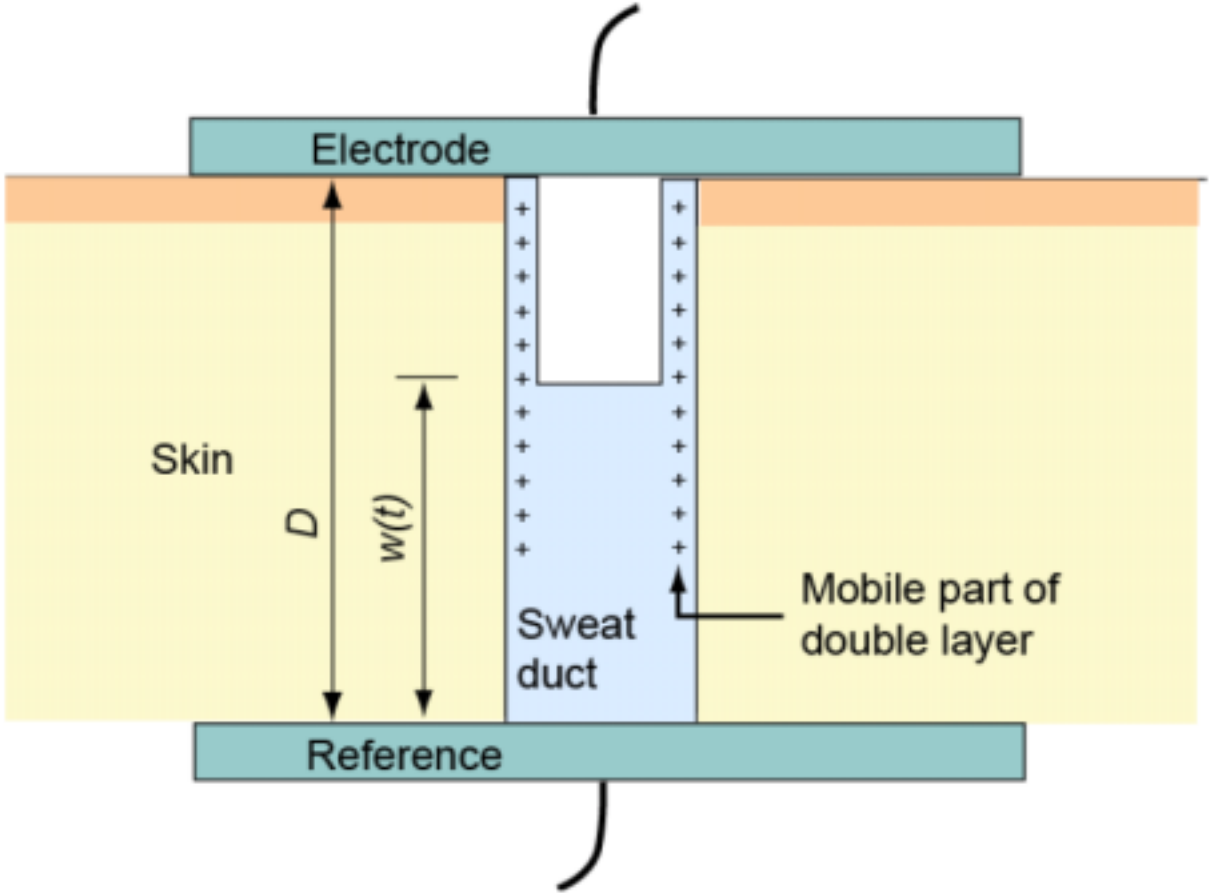
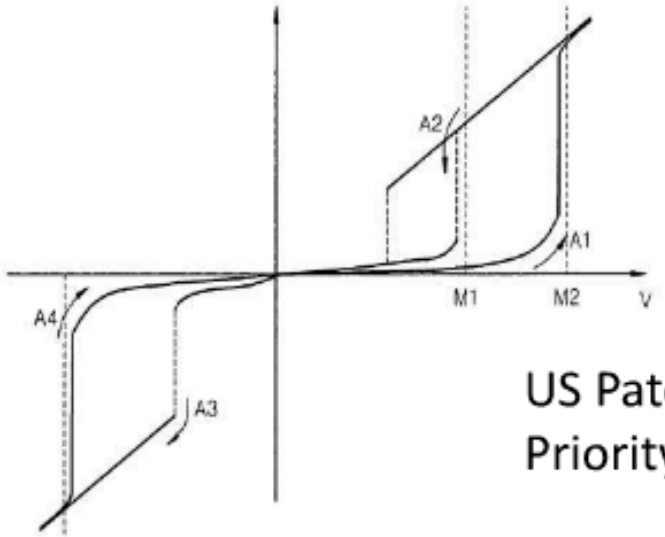


Figure 2: Schematic model of sweat duct in human epidermis.

APPLICATIONS
Non-volatile memory

- First memory prototype (4 Mb, 180 nm) announced by SONY: W. Oksuka *et al., 2011*
- HP announced for 2013

Samsung (not HP) holds basic U.S. patent for TiO_{2-x}/TiO_2 resistance memory[1]



US Patent 7,417,271 (Fig. 4),
Priority Feb. 27, 2006

Nature Precedings : hdl:10101/npre.2009.3010.1 : Posted 31 Mar 2009

Memristance can explain Spike-Time-Dependent-Plasticity in Neural Synapses

Bernabé Linares-Barranco and Teresa Serrano-Gotarredona

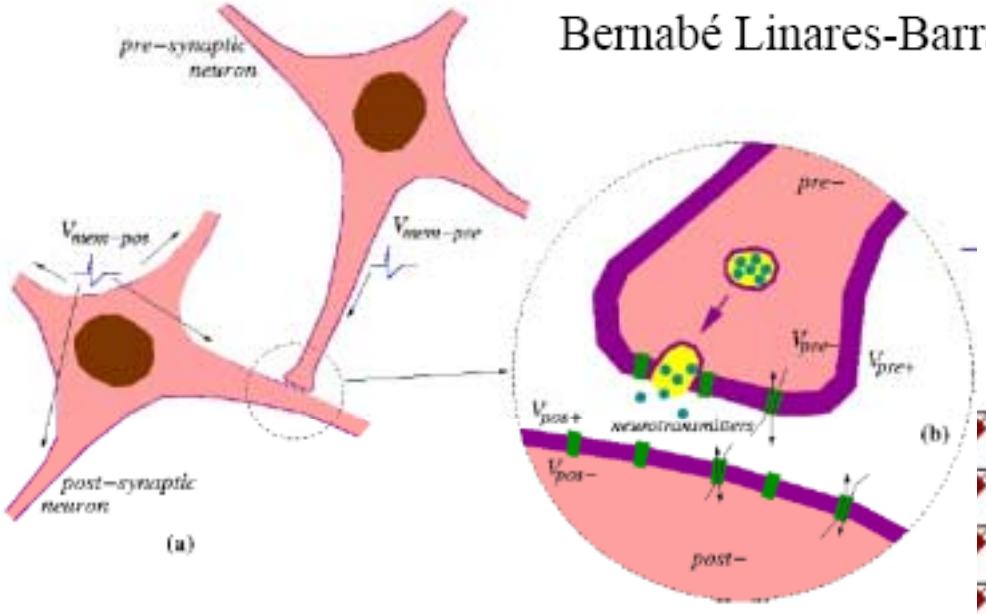


Figure 2 | Illustration of synaptic action. a. A synapse is where a pre-synaptic neuron "connects" with a post-

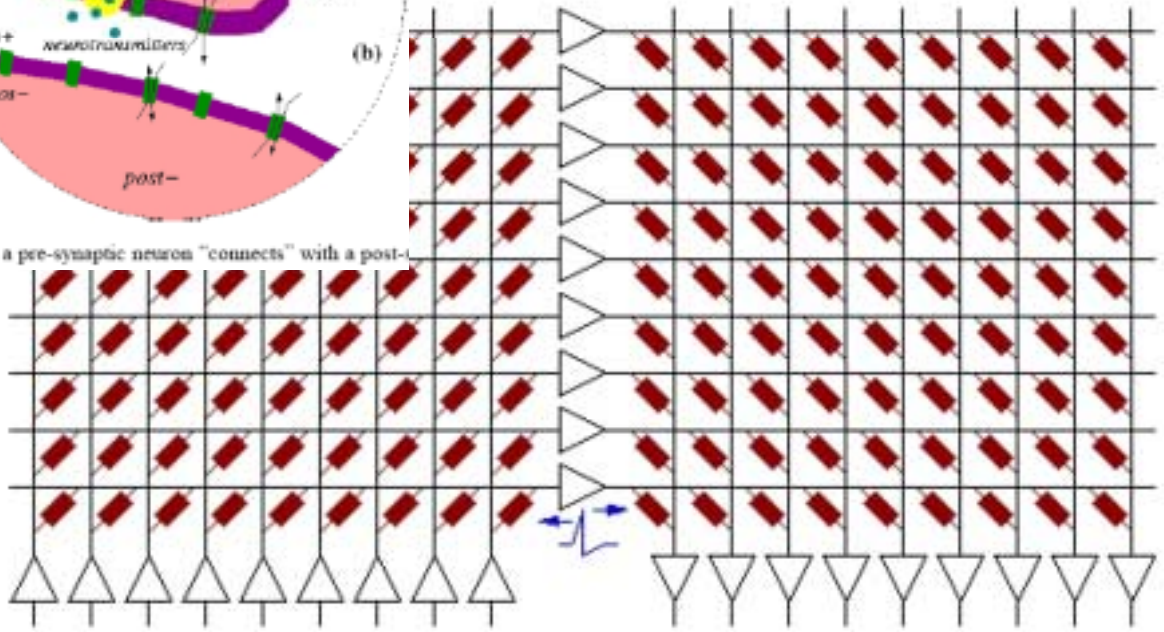
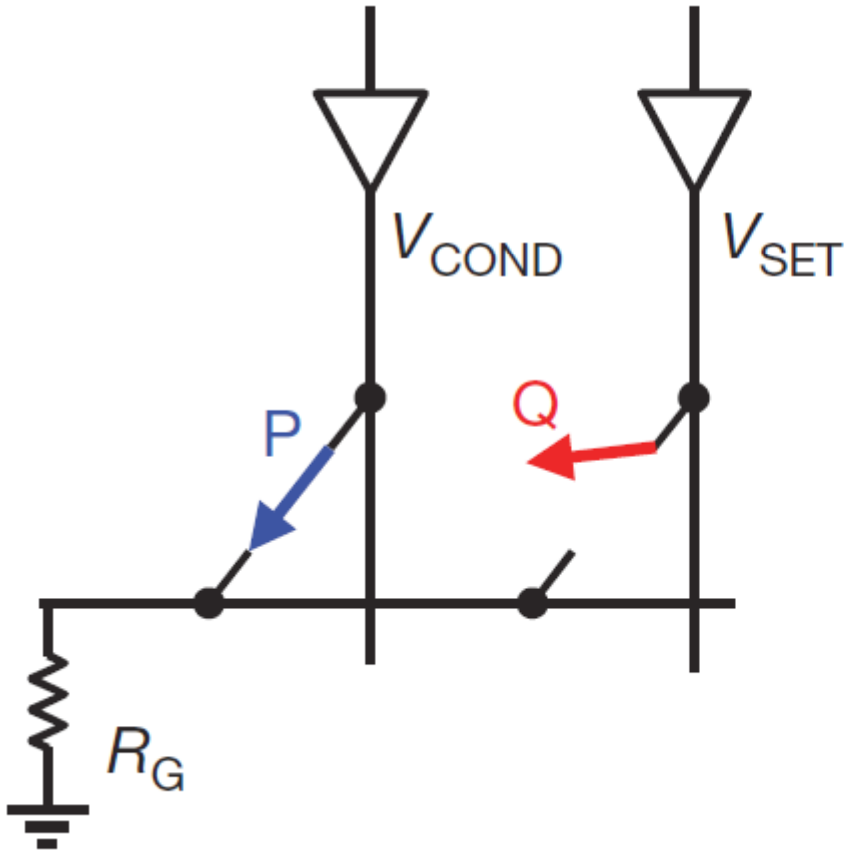


Figure 5 | Neuromorphic memristive computer equipped with STDP.

Vol 464|8 April 2010|doi:10.1038/nature08940 nature

'Memristive' switches enable 'stateful' logic operations via material implication

Julien Borghetti[1], Gregory S. Snider[1], Philip J. Kuekes[1], J. Joshua Yang[1], Duncan R. Stewart[1]† & R. Stanley Williams[1]



$q' \leftarrow p\mathrm{IMP}q$

In p	In q	Out q'
0	0	1
0	1	1
1	0	0
1	1	1

Greg Snider, Rick Amerson, Dick Carter, Hisham Abdalla, and Muhammad Shakeel Qureshi
Hewlett-Packard Laboratories

Jasmin Léveillé, Massimiliano Versace, Heather Ames, Sean Patrick, Benjamin Chandler, Anatoli Gorchetchnikov, and Ennio Mingolla, *Boston University*

From Synapses to Circuitry: Using Memristive Memory to Explore the Electronic Brain

(a)

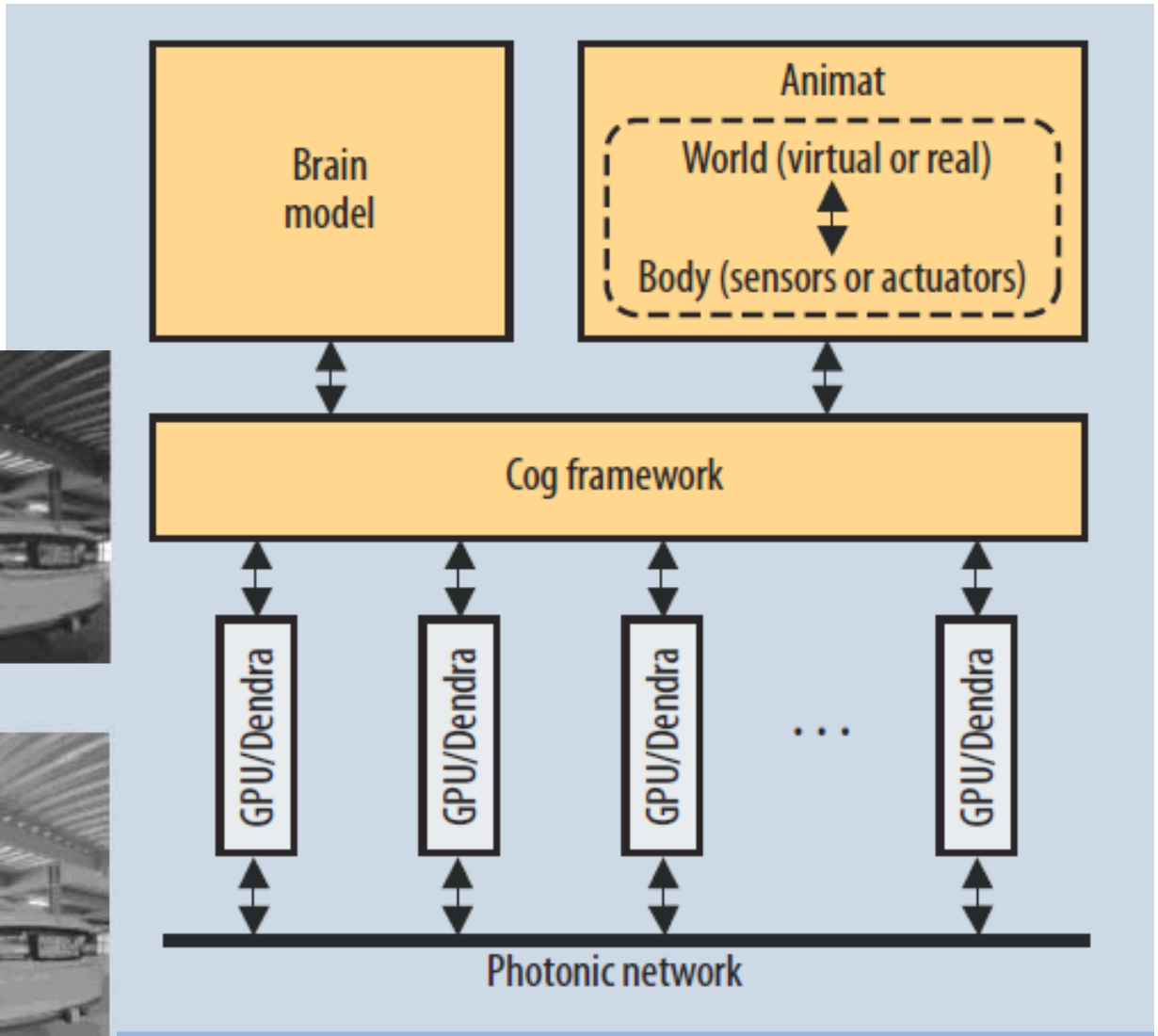


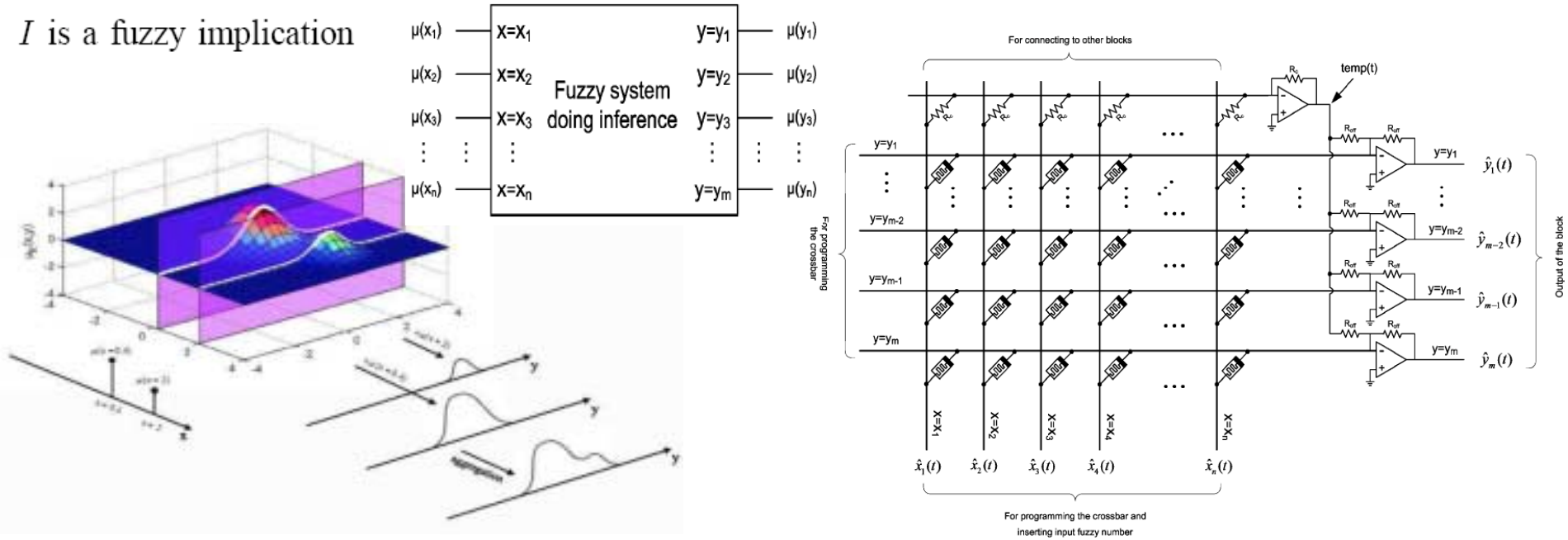
Figure 1. High-level view of the Cog Ex Machina platform.

Efficient neuro-fuzzy system and its Memristor Crossbar-based Hardware Implementation

Farnood Merrikh-Bayat and Saeed Bagheri-Shouraki

$$\mu_R(x,y) = I(\mu_A(x), \mu_B(y)) = f(\mu_A(x) + \mu_B(y)),\ \forall x \in X \text{ and } y \in Y,$$

I is a fuzzy implication



arXiv:1103.1156v1 [cs.AI] 6 Mar 2011

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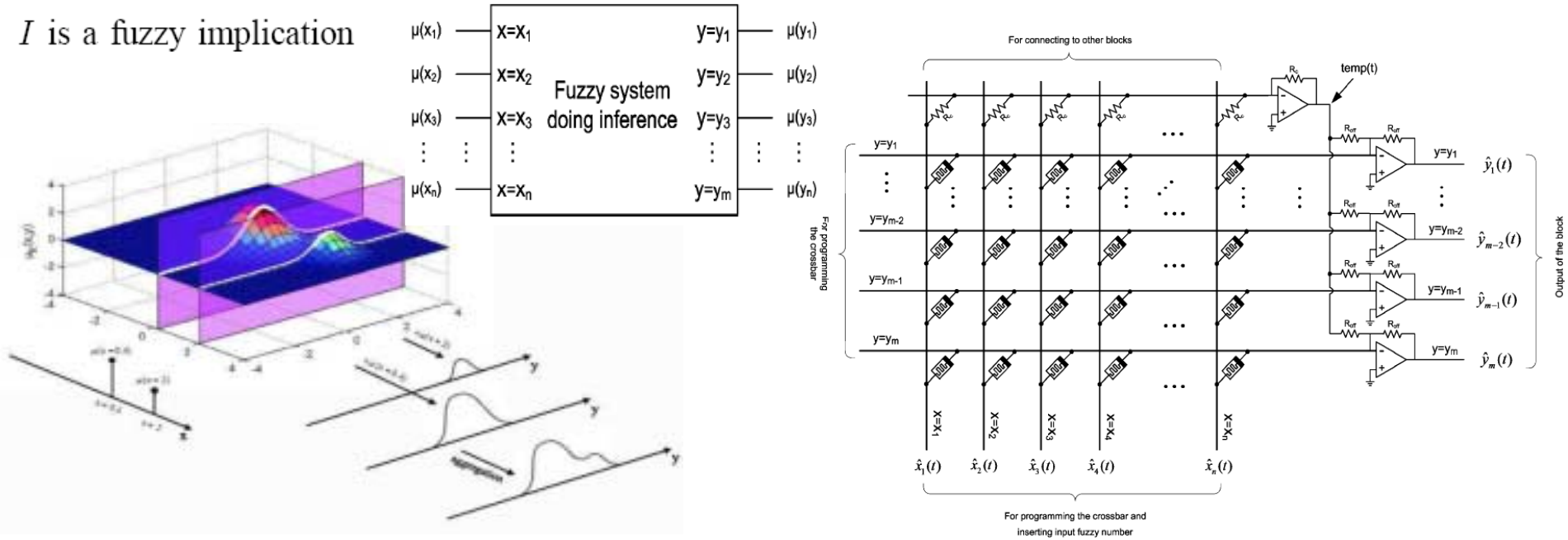


For example, consider *min* and *max* operators which are frequently in use in fuzzy inference systems. It is well known that their hardware implementation is not efficient compared to some other t-norm or t-conorm operators. Therefore, it is evident that the construction of large scale systems like human brain based on these inference methods is very hard if not impossible.

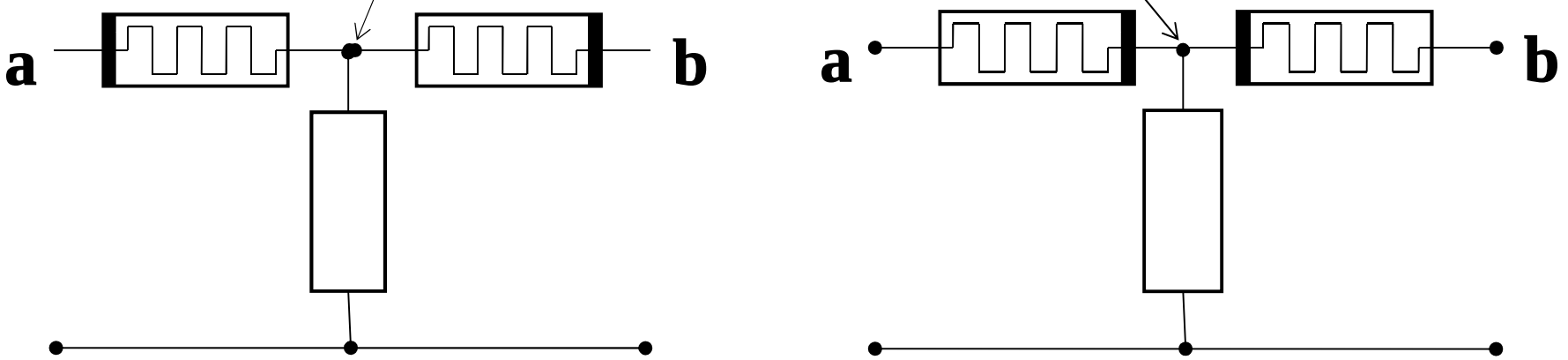
Memristors can implement fuzzy logic

Martin Klimo, Ondrej Šuch

arXiv:1110.2074 (2011).

$$a \oplus b \sim \max(a, b)$$

$$a \otimes b \sim \min(a, b)$$



\+ simple, passive, non-volatile => low energy consumption

\- negation (1-x) not available

On the Complexity of MAX/MIN/AVRG Circuits

Manuel Blum Rachel Rue Ke Yang School of Computer Science
Carnegie Mellon University
Pittsburgh, PA 15213

March 29, 2002
CMU-CS-02-110

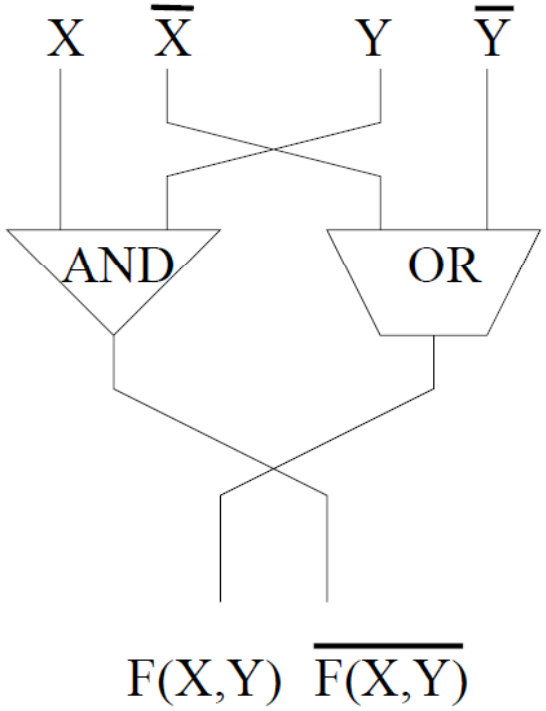
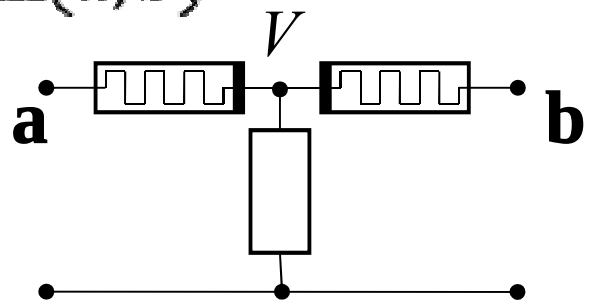


Figure 8: Using monotone circuit to simulate any circuit

Déjà vu property

$\min(a, b)$

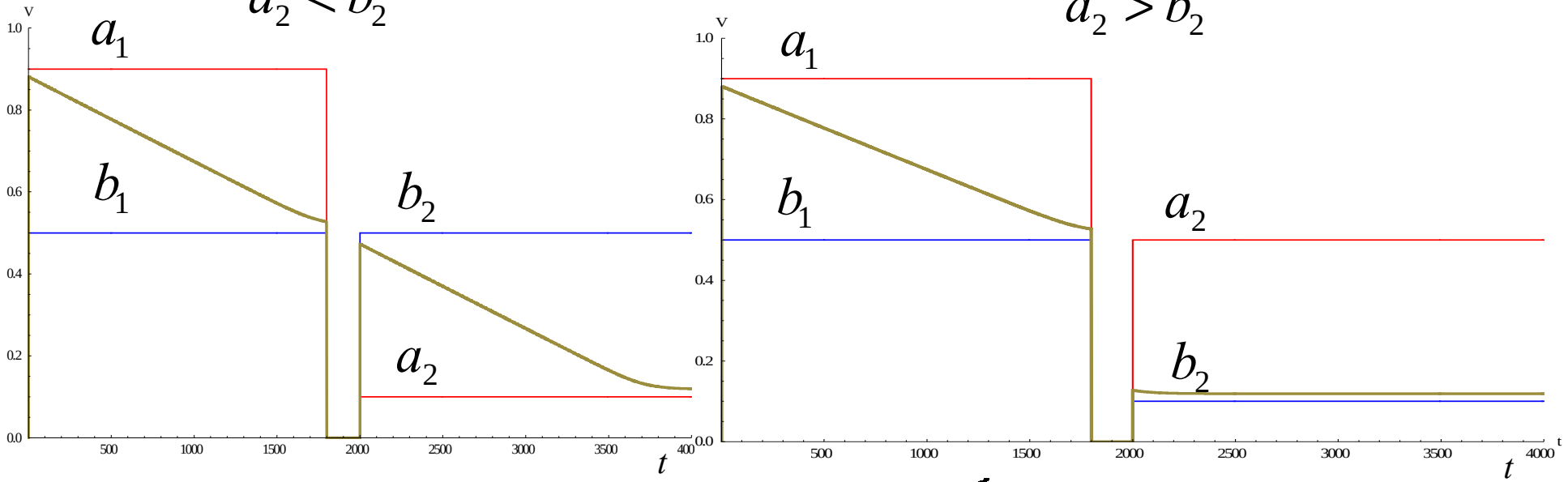


$a_1 > b_1$

$a_2 < b_2$

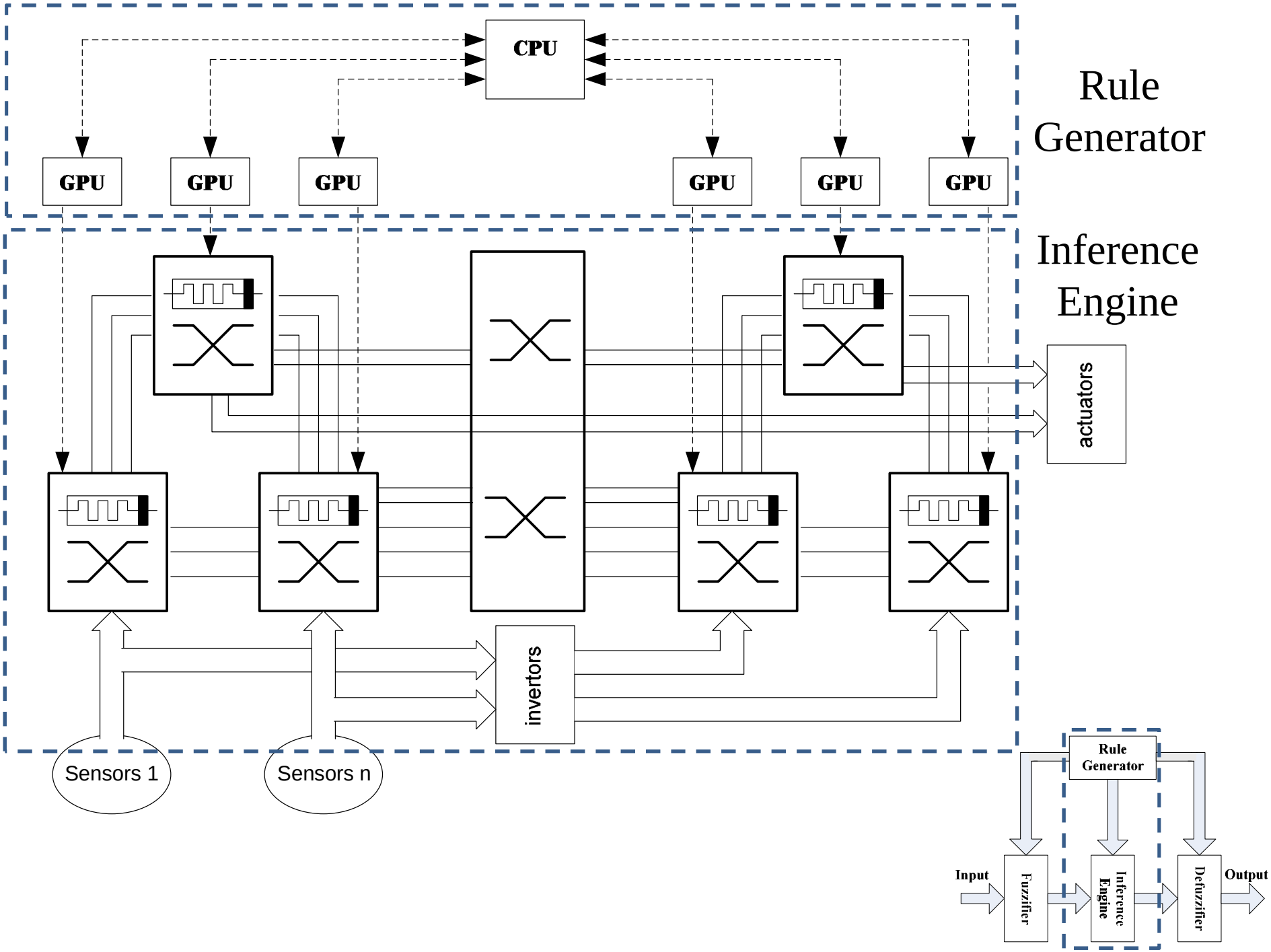
$a_1 > b_1$

$a_2 > b_2$

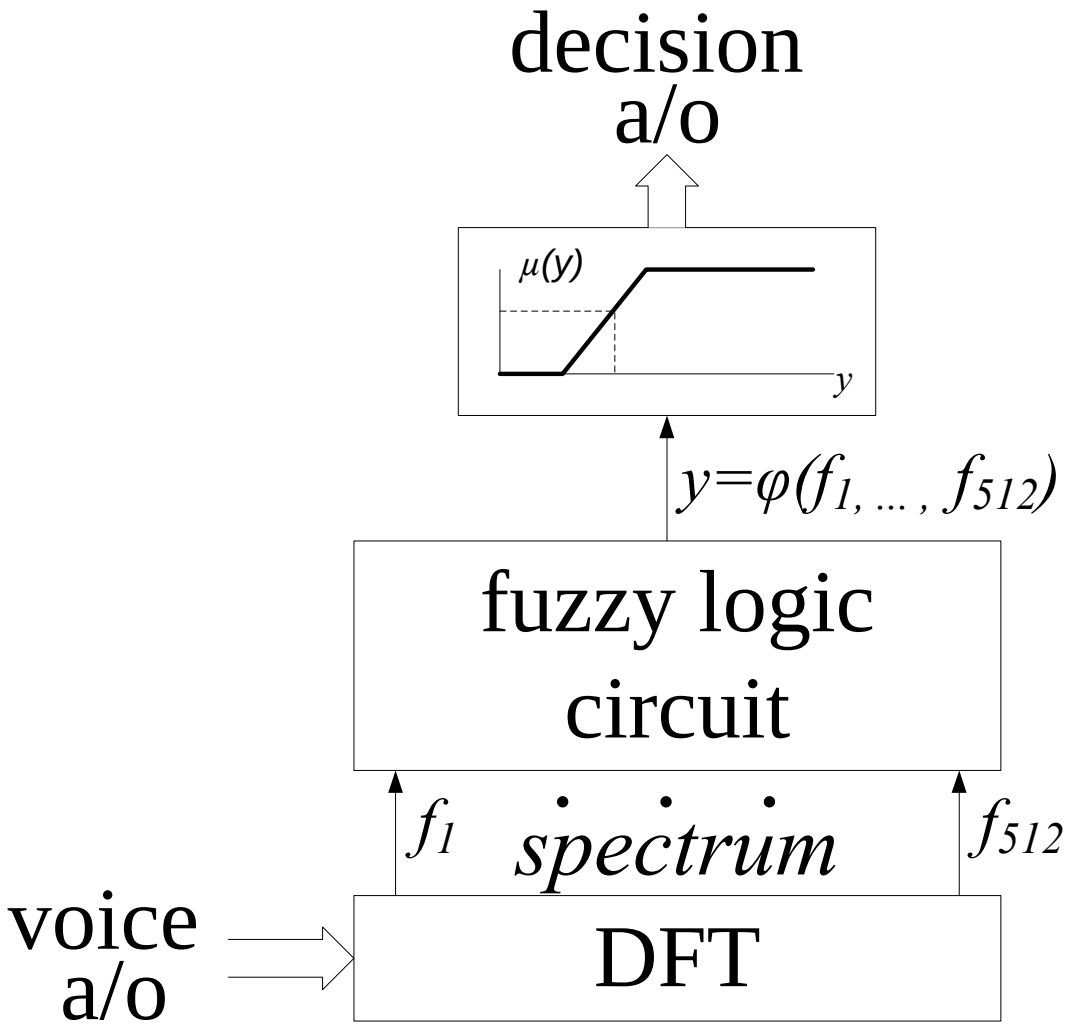


$$u(t) = (R_{on}\frac{w}{D} + R_{off}\frac{1-w}{D})i(t)$$

$$\frac{dw}{dt} = kf(w)i(t)$$

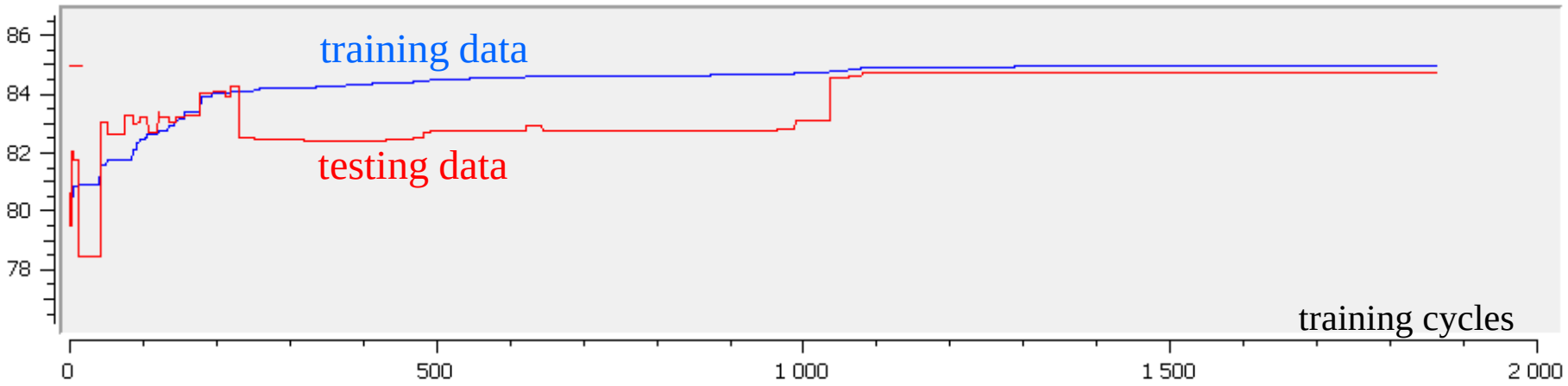

CPU
GPU
GPU
GPU
GPU
GPU
GPU
Rule Generator
Inference Engine
actuators
invertors
Sensors 1
Sensors n
Rule Generator
Input
Fuzzifier
Inference Engine
Defuzzifier
Output

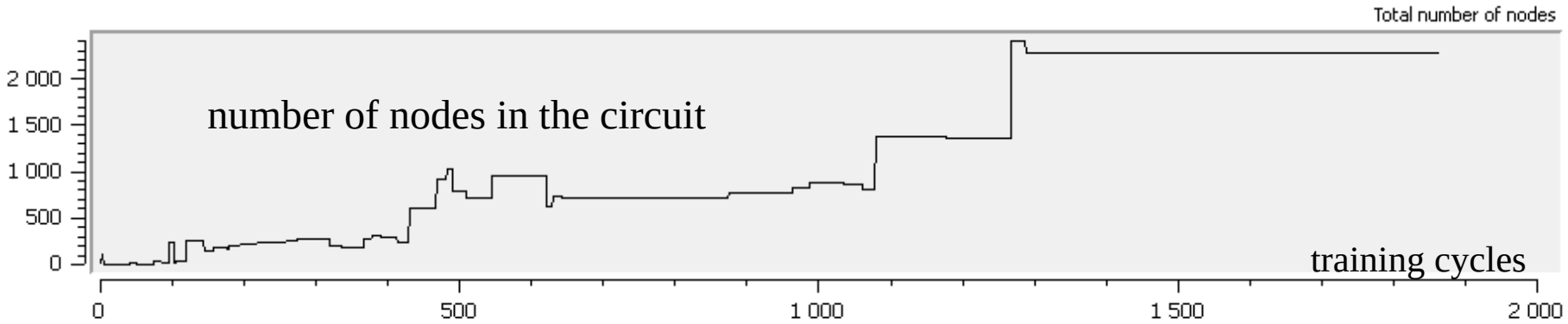
Example: vowel recognition

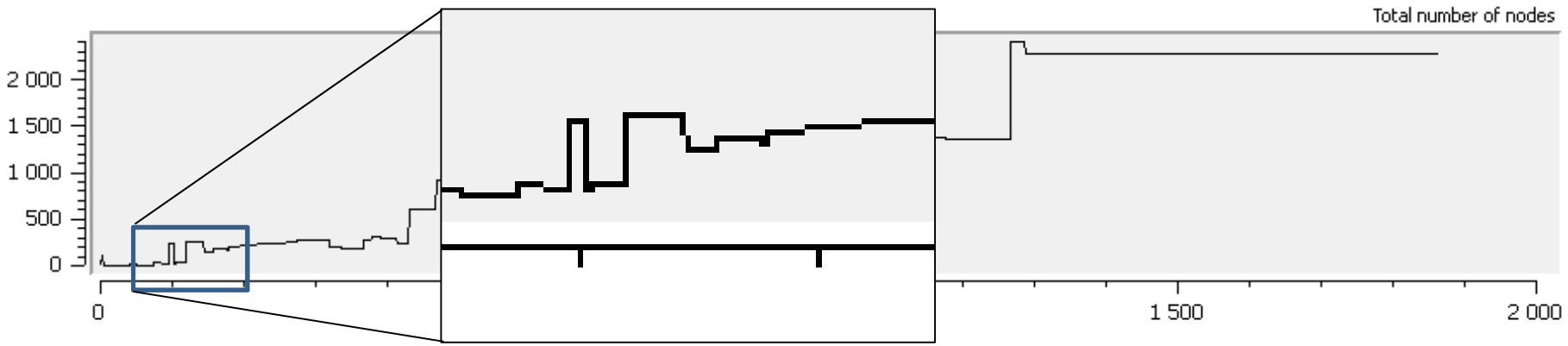


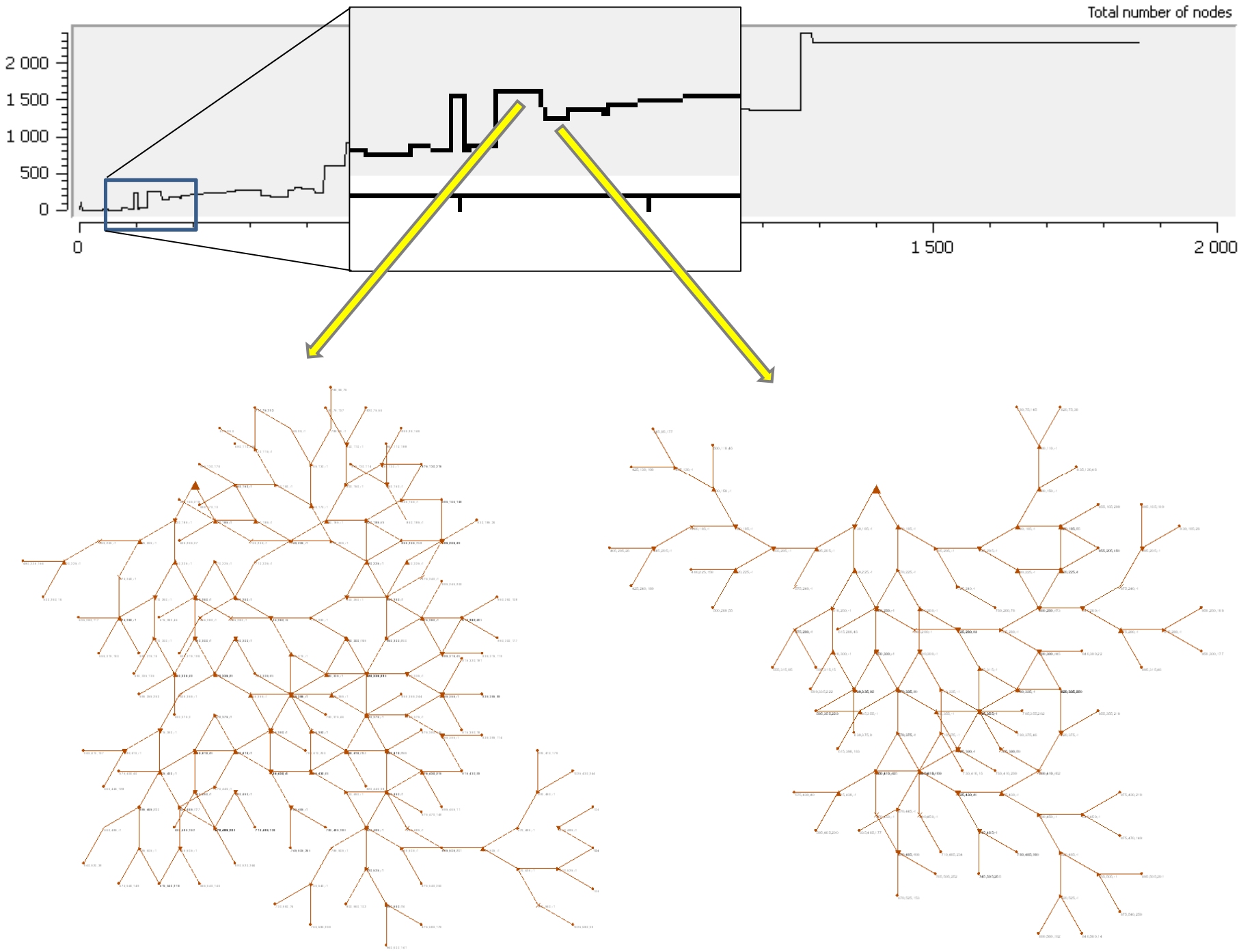
Fuzzy logic circuit optimisation

- Circuit elements limited to **min, max, avg, neg**
- Circuit topology limited to **fractal structure**
- Optimal „gene“ searched by **genetic algorithm**

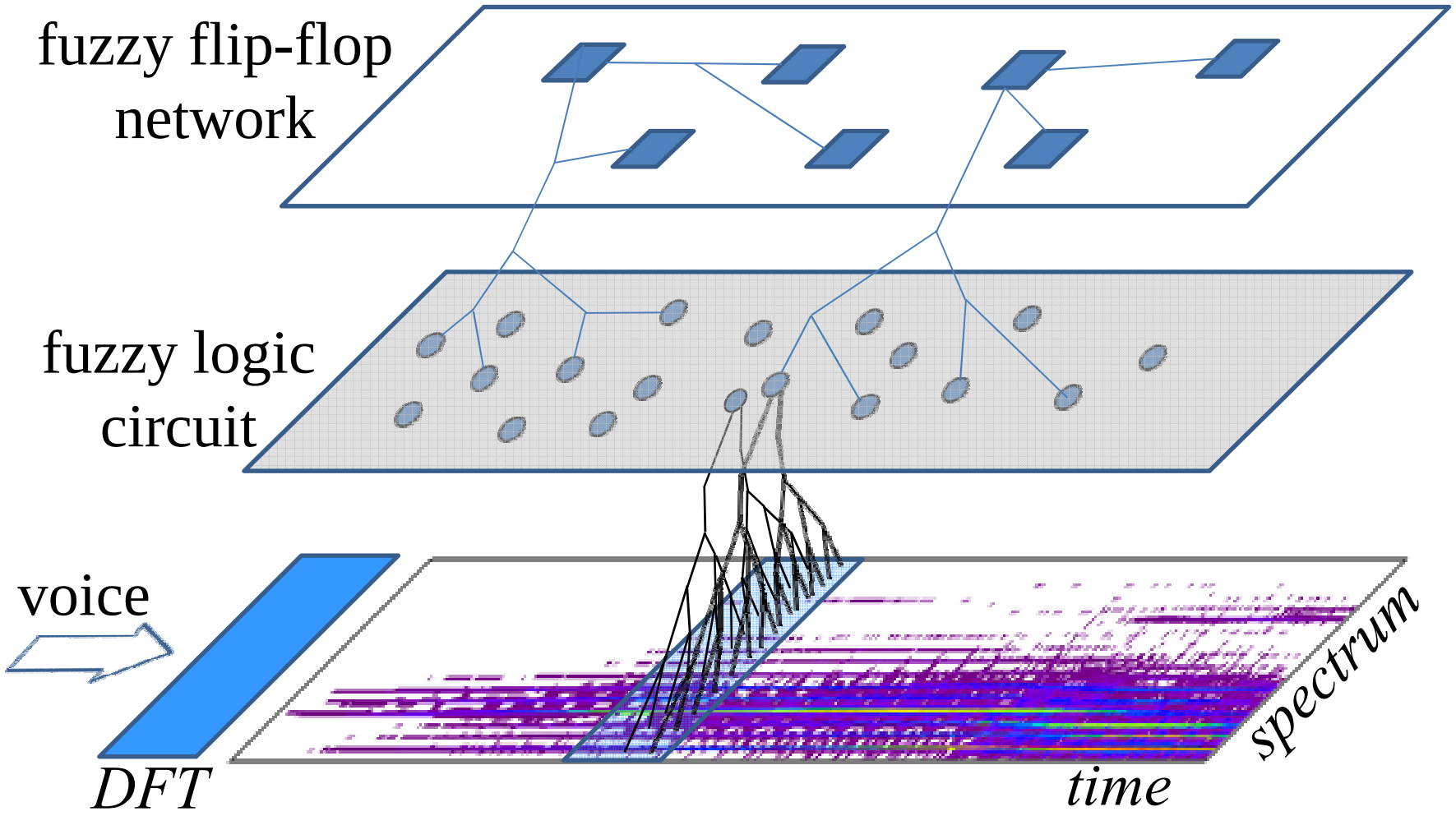





Total number of nodes
2 000
1 500
1 000
500
0
0
1 500
2 000


Total number of nodes
2 000
1 500
1 000
500
0
0
1 500
2 000

Future research



Thank you
for your attention