NeuroAgents
Neuromorphic intelligence on DYNAP

Open Source Brain 2019

Alghero – Sardinia

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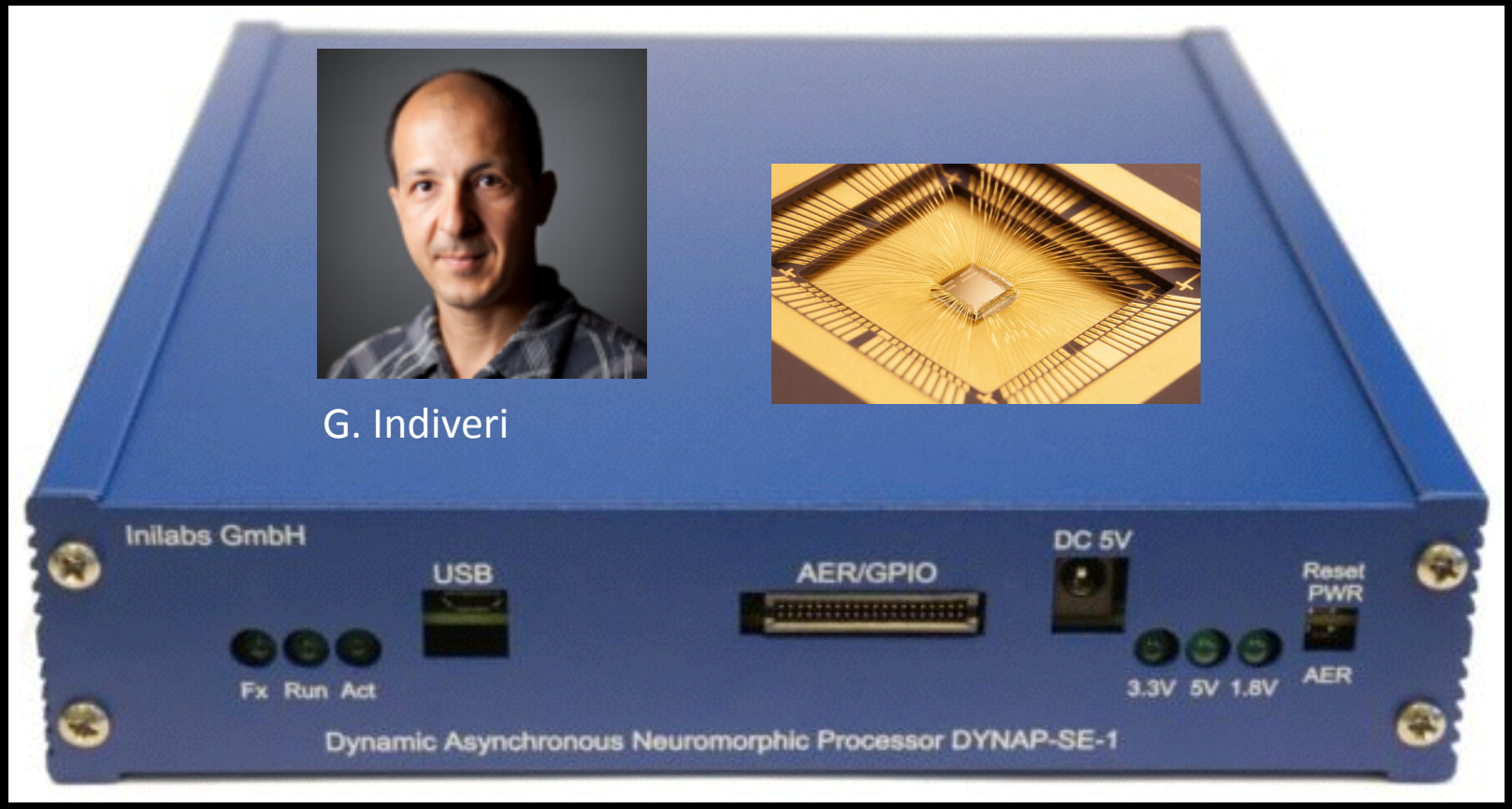
erc European Research Council

DYNAP
Dynamic Neuromorphic Asynchronous Processors

Emulation ~~Simulation~~



Analog subthreshold circuits

for emulating the biophysics of proteic channels

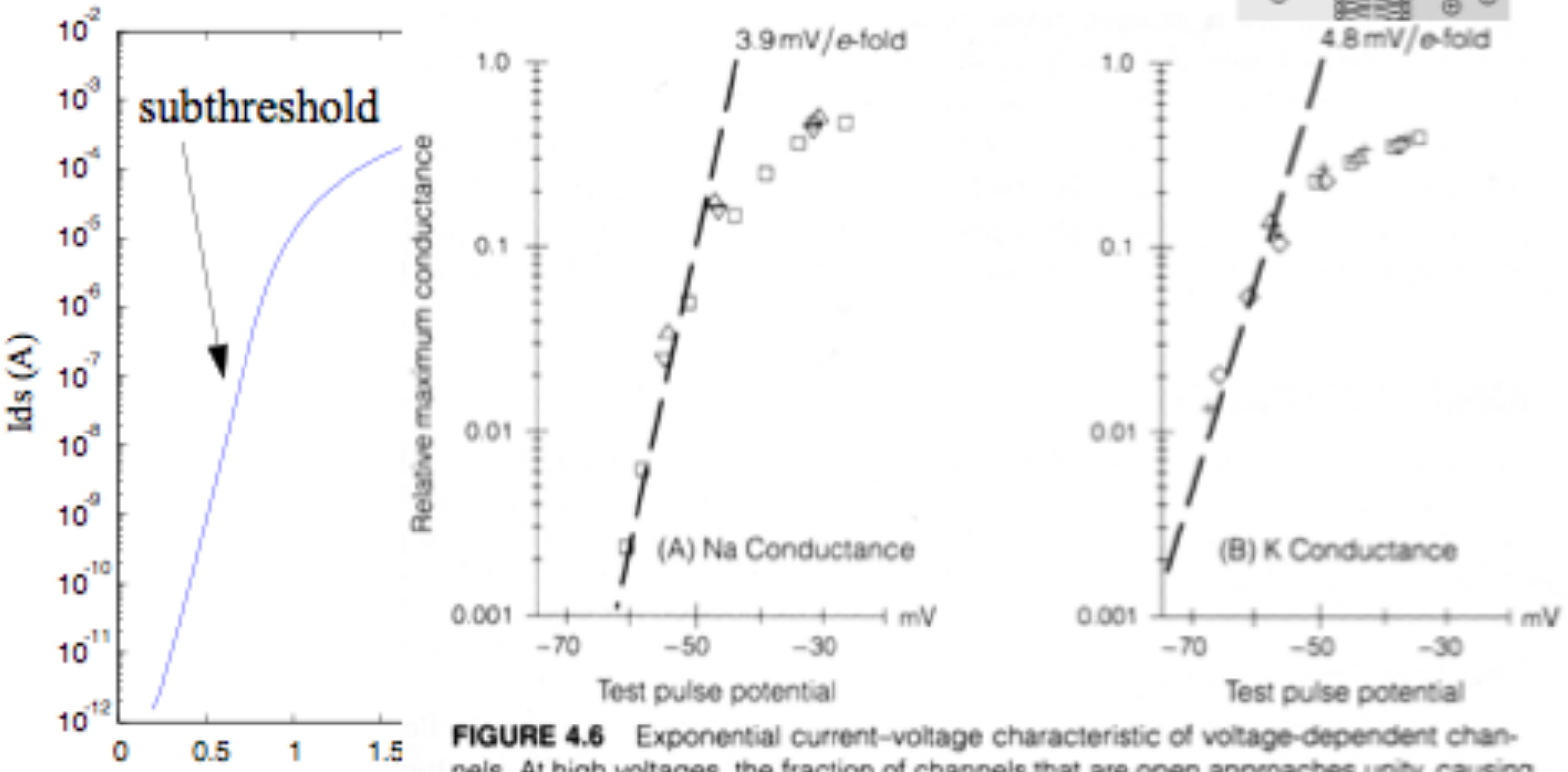
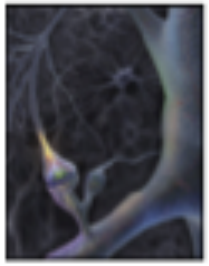
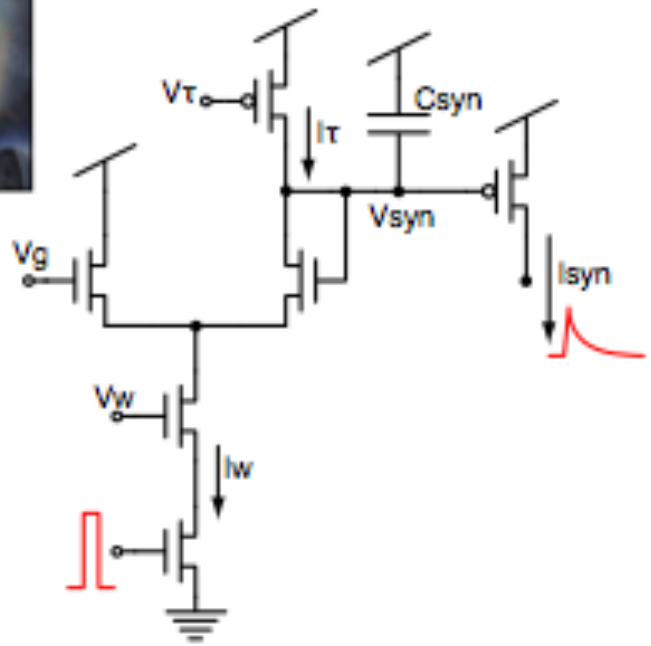


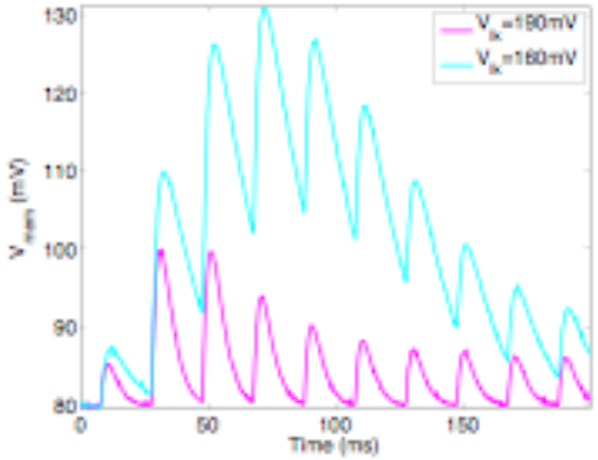
FIGURE 4.6 Exponential current–voltage characteristic of voltage-dependent channels. At high voltages, the fraction of channels that are open approaches unity, causing a saturation of the curves. (*Source:* [Hodgkin et al., 1952b, p. 464].)

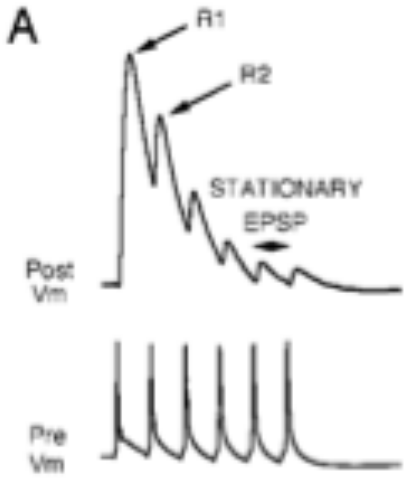
Synapse analog circuit

for implementing slow temporal dynamics





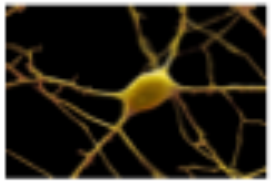


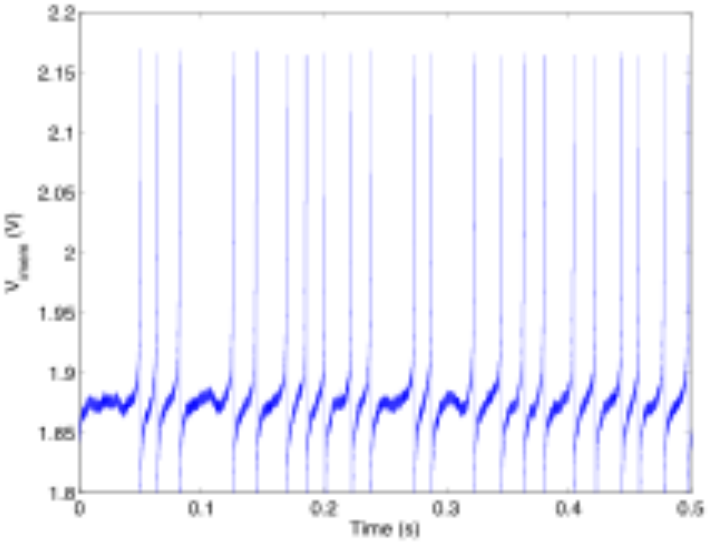


[Bartolozzi and Indiveri, 2007] [Bache & Habnloser, 2001] [Boegerhausen, et al., 2003]

Silicon neuron circuit

with spike-frequency adaptation and exponential dynamics





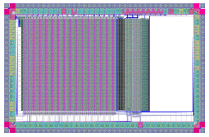
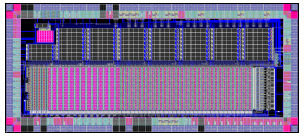
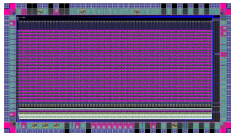
$$\tau \frac{d}{dt} I_{mem} + I_{mem} \approx \frac{I_{th} I_{in}}{I_\tau} - I_g + f\left(I_{mem}\right)$$

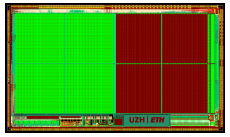
$$\tau_{ahp} \frac{d}{dt} I_g + I_g = \frac{I_{thr} I_{ahp}}{I_{\tau_{ahp}}}$$

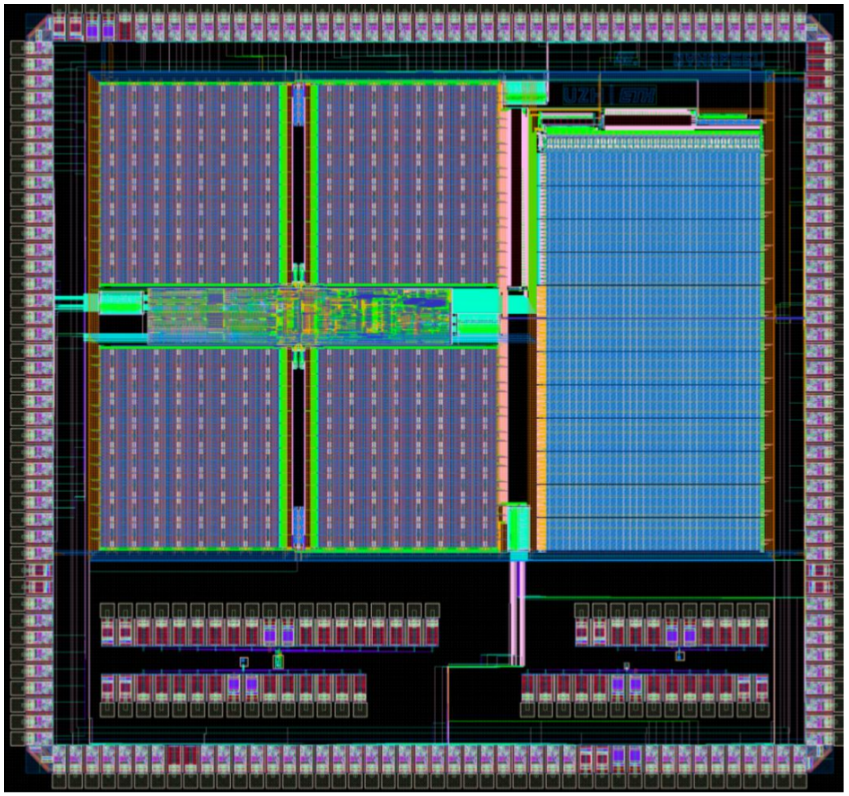
[Indiveri et al., ISCAS 2010]

Mixed signal neuromorphic processor designs

DYNAP-SEL: Dynamic Neuromorphic Asynch Processor with Self Learning





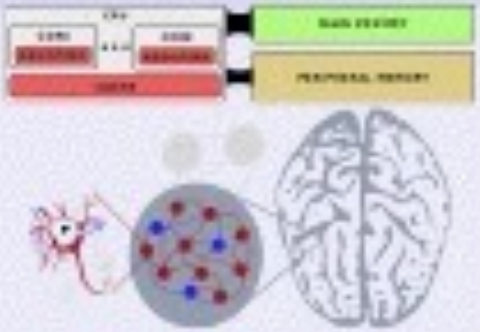
Chip Name	DynapSEL
Process	ST28FDSOI
Supply Voltage	1V
IO Number	176 + (internal 59)
Chip area	2.8mm x 2.6mm
Core Numbers	4 non-plastic cores 1 plastic core
Neuron Type	Analog AExp I&F
Non-plastic Synapse Type	TCAM based 4-bit
Plastic Synapse Type	Linear 4-bit digital
Throughput of Router	1G Events/second
Scalability	16 x16 chips non-plastic core) 4 x4 chips (plastic cores)

Brain-inspired computing hardware

To reach the 20W figures, we need a radical paradigm shift in computing!

Exploit physical space

- Multiple instances of similar computing elements.
- Memory and computation co-localized.
- Sparse activation, massive parallelsim.
- Continuous time. Data driven processing.



Let time represent itself

- For interacting with the environment in real-time.
- Dynamics with time constants matched to the input signals.
- Inherently synchronized with the real-world "natural" events.
- To process sensory signals efficiently (low power, low bandwidth).

Applications
&
HOW TO …

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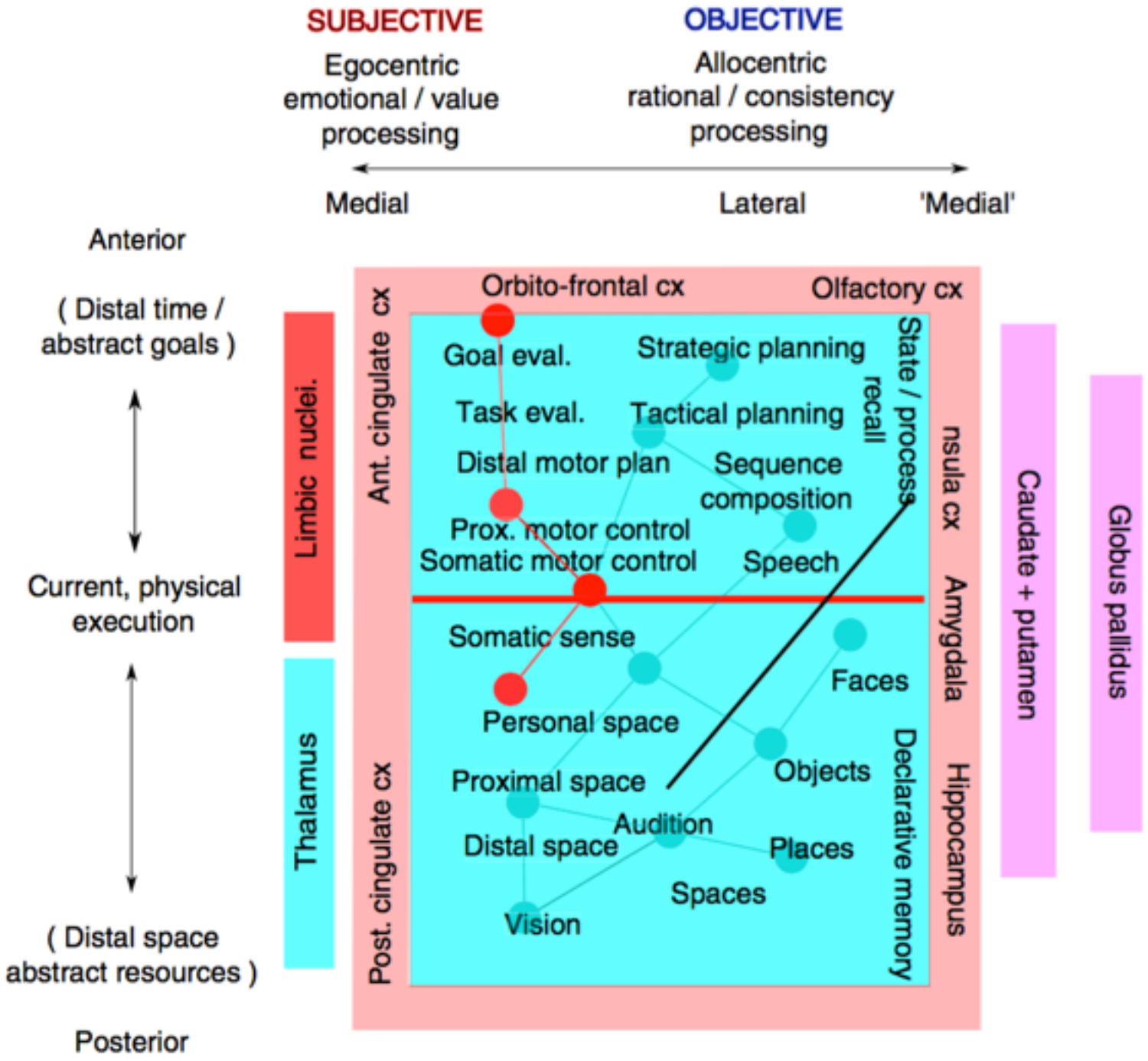
…**artificial behaving systems** that can be programmed to carry out complex tasks in **uncontrolled** environments and that can operate **autonomously**, **adapting to unexpected** changes in the environment, while being able to **cope with noise and uncertainty** in both the input signals and **their internal states**.



Douglas & Martin 2012, Current Biology Vol 22 No 24

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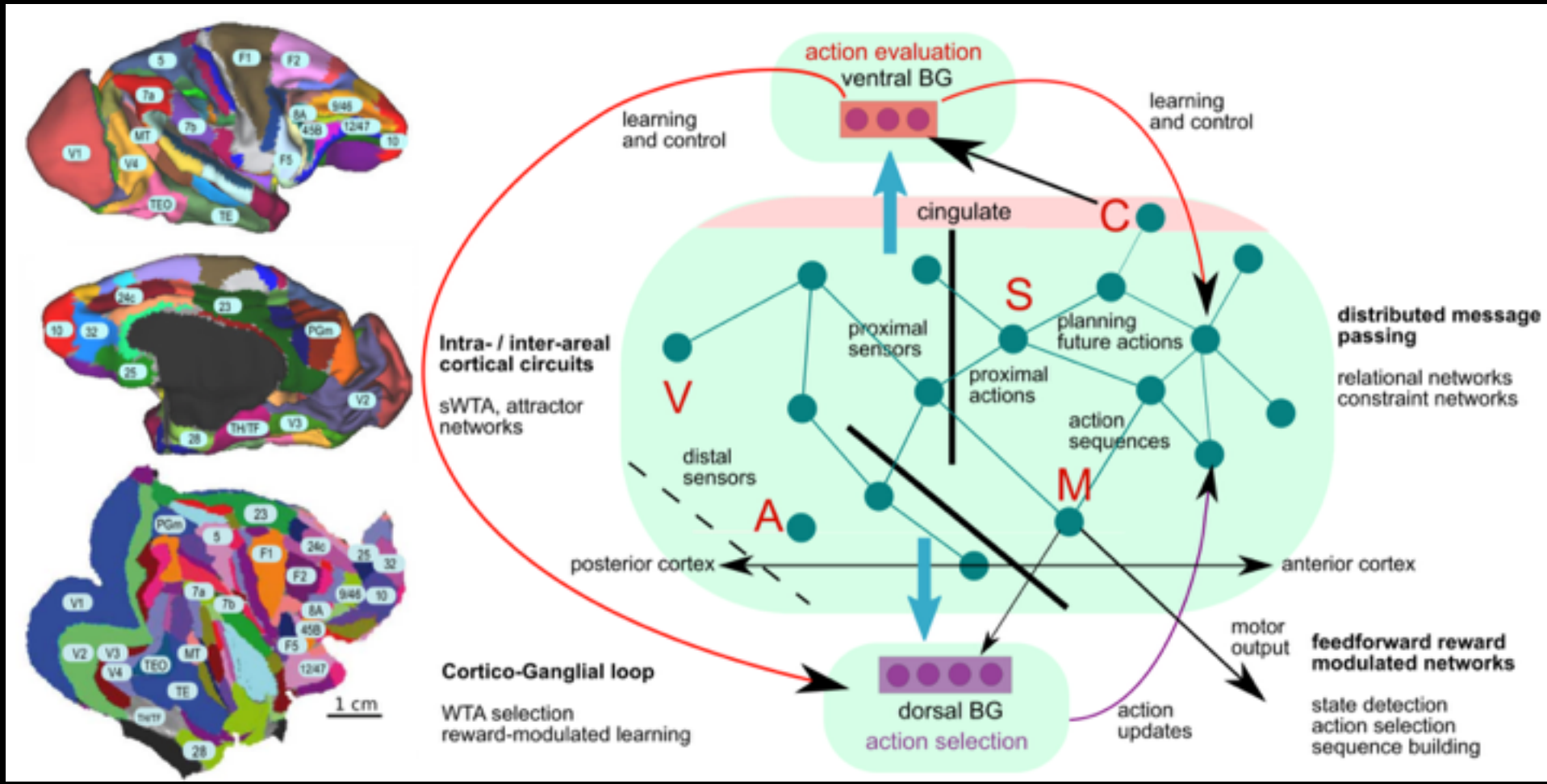

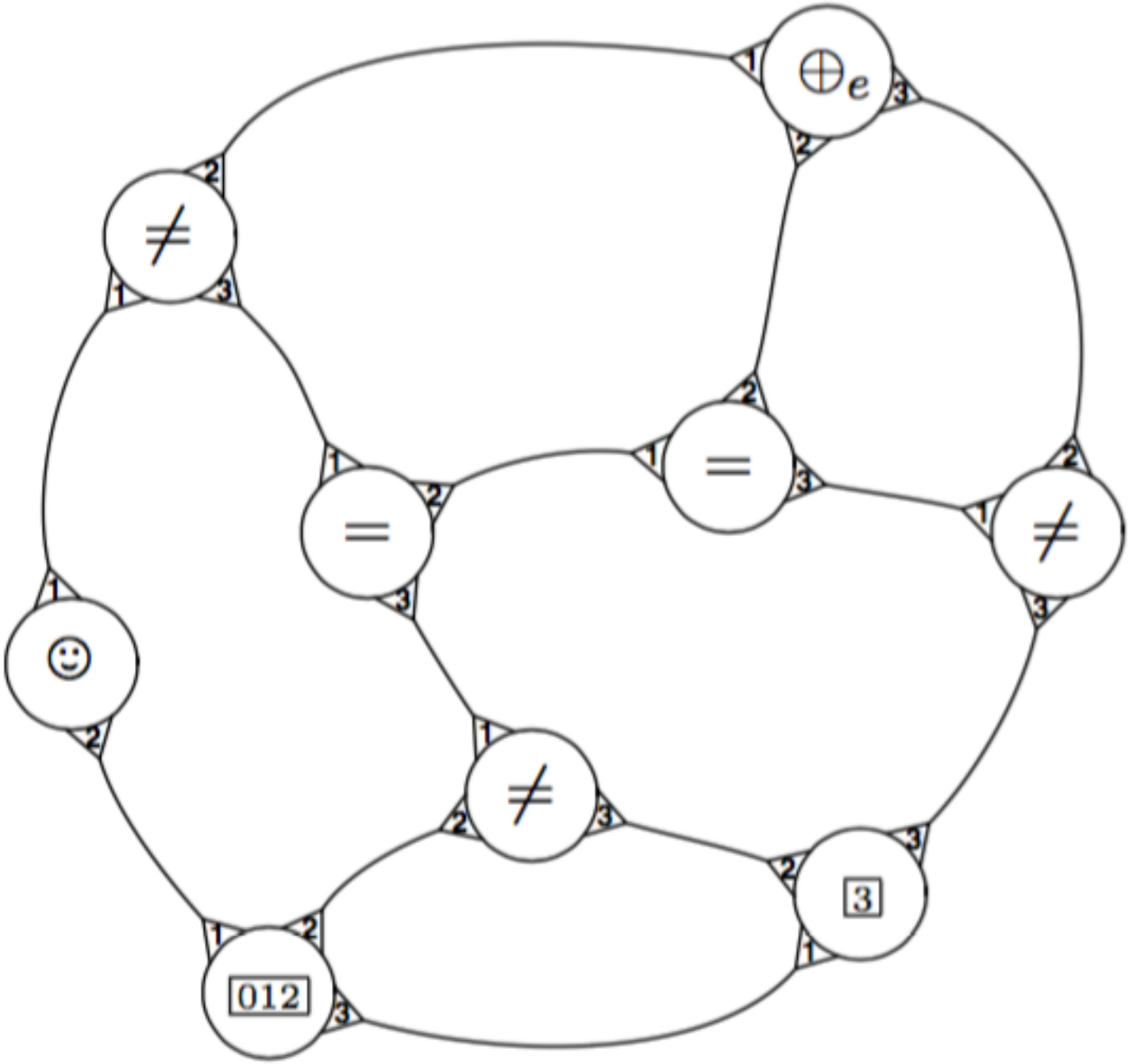
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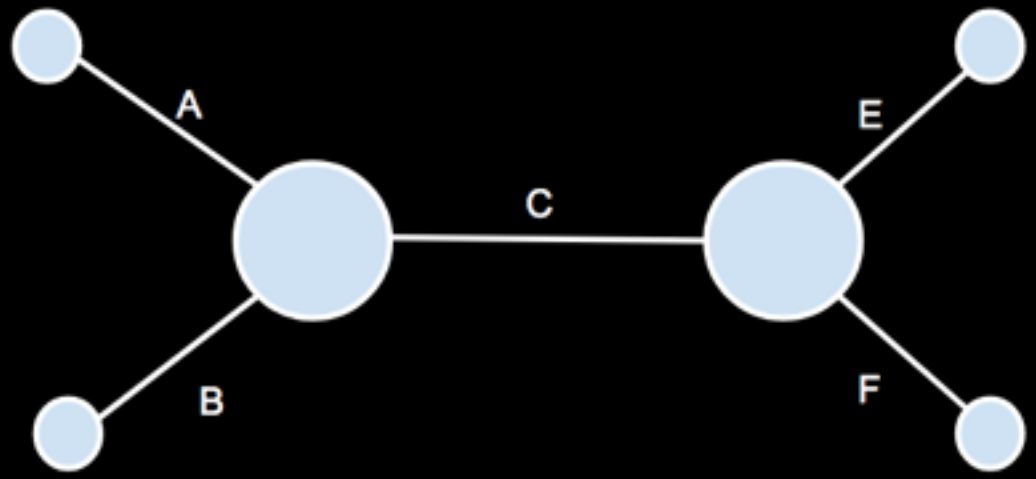
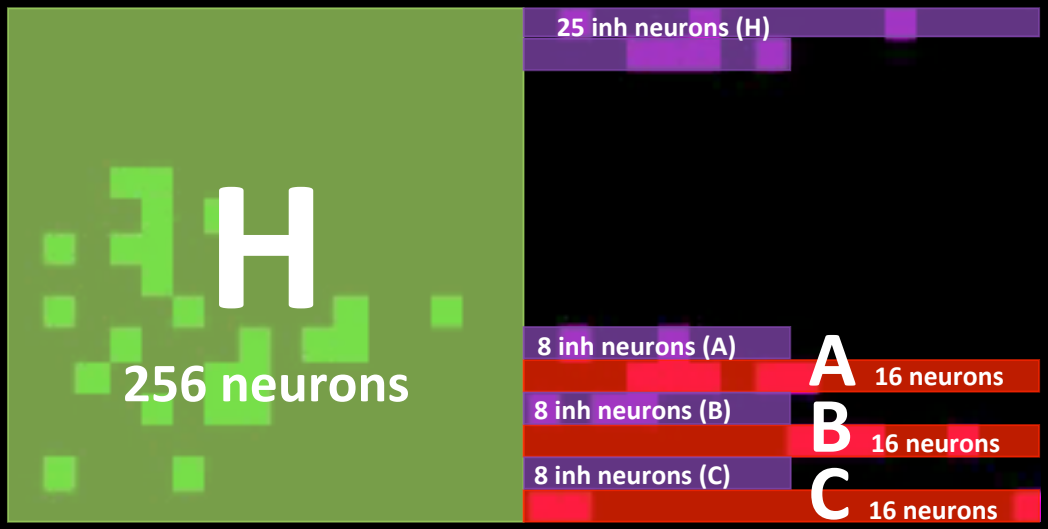
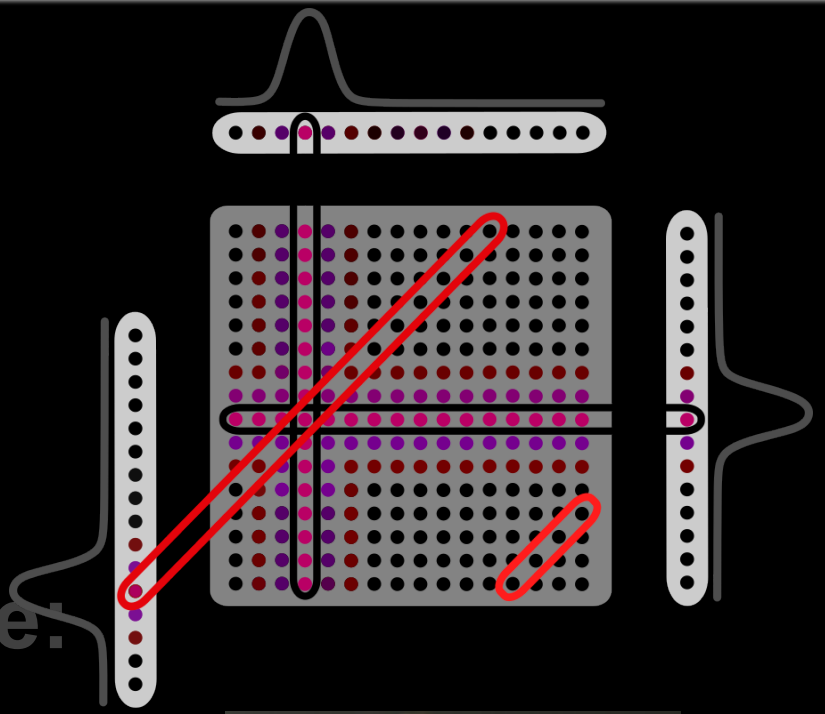
Basic network node



3-Ways network node





Omnidirectional inference:

(A, B) → C
(A, C) → B
(B, C) → A

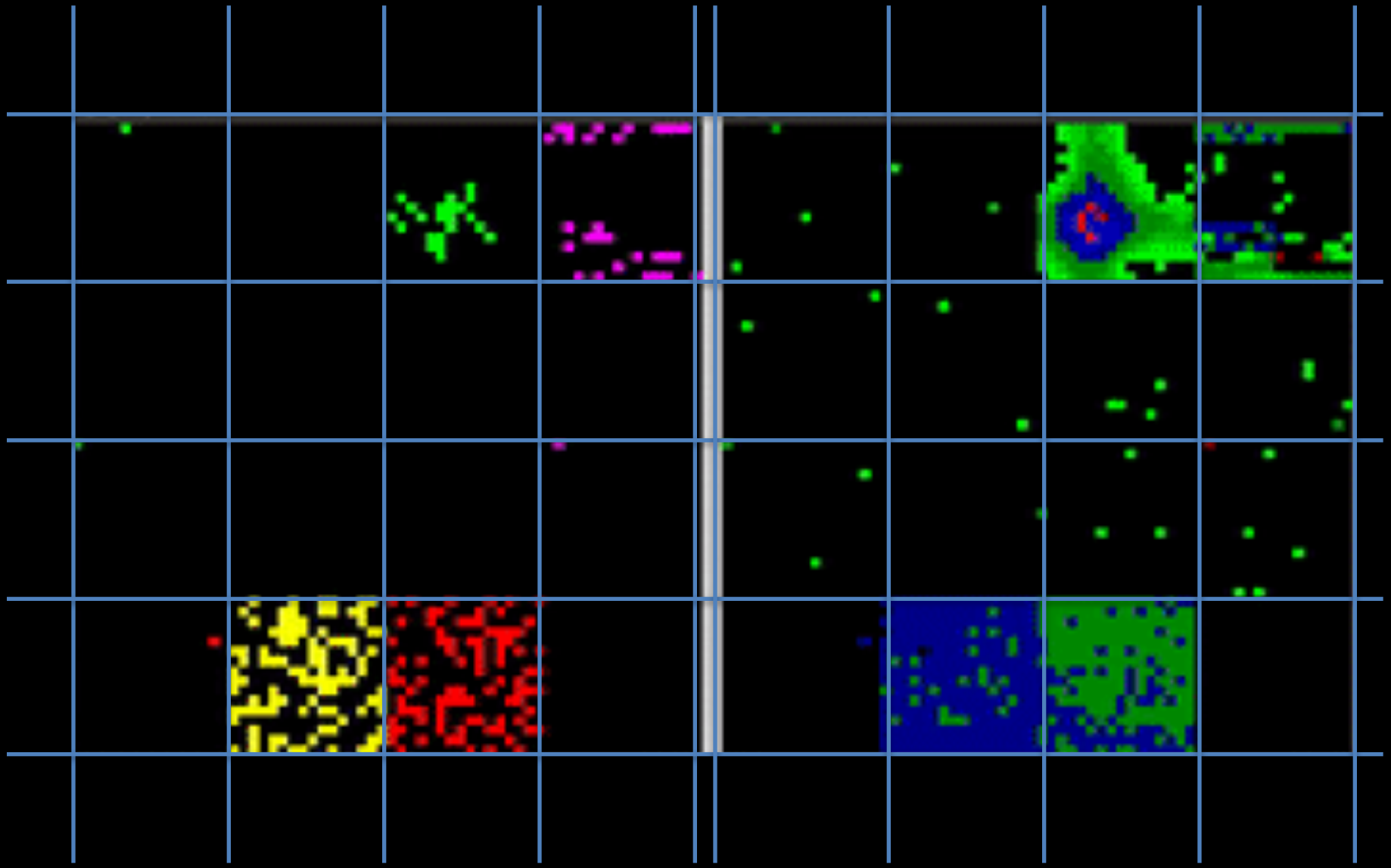
"Hard-wired" implementation of

A + B = C

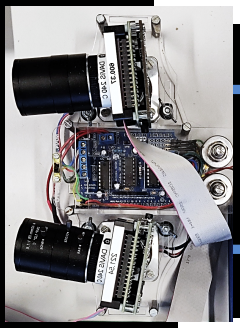
Dmitrii Zendrikov

Deneve, Latham and Pouget, 2001 Nat. Neurosci.

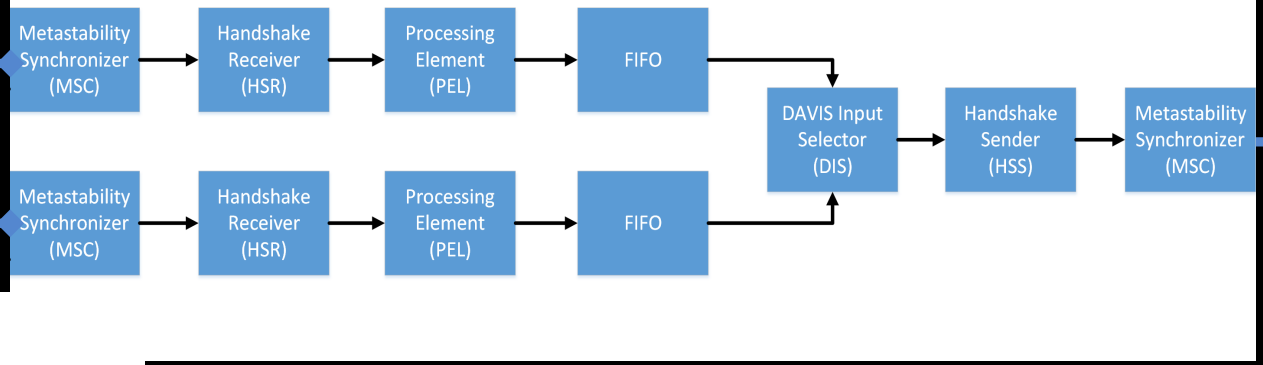
3-Ways network node

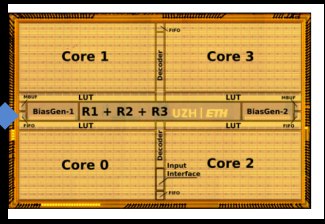


Stereo Vision



stereo
DAVIS240C

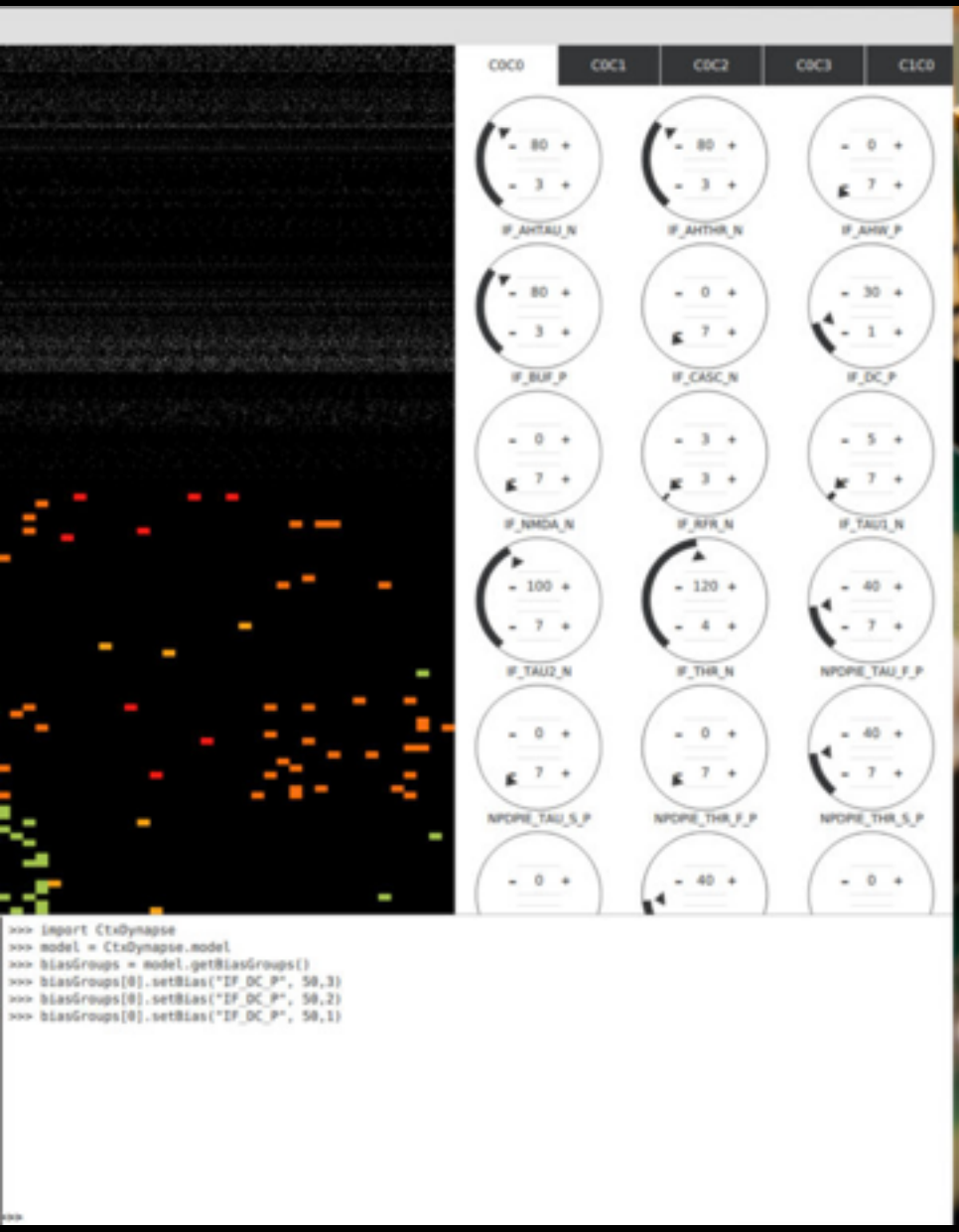


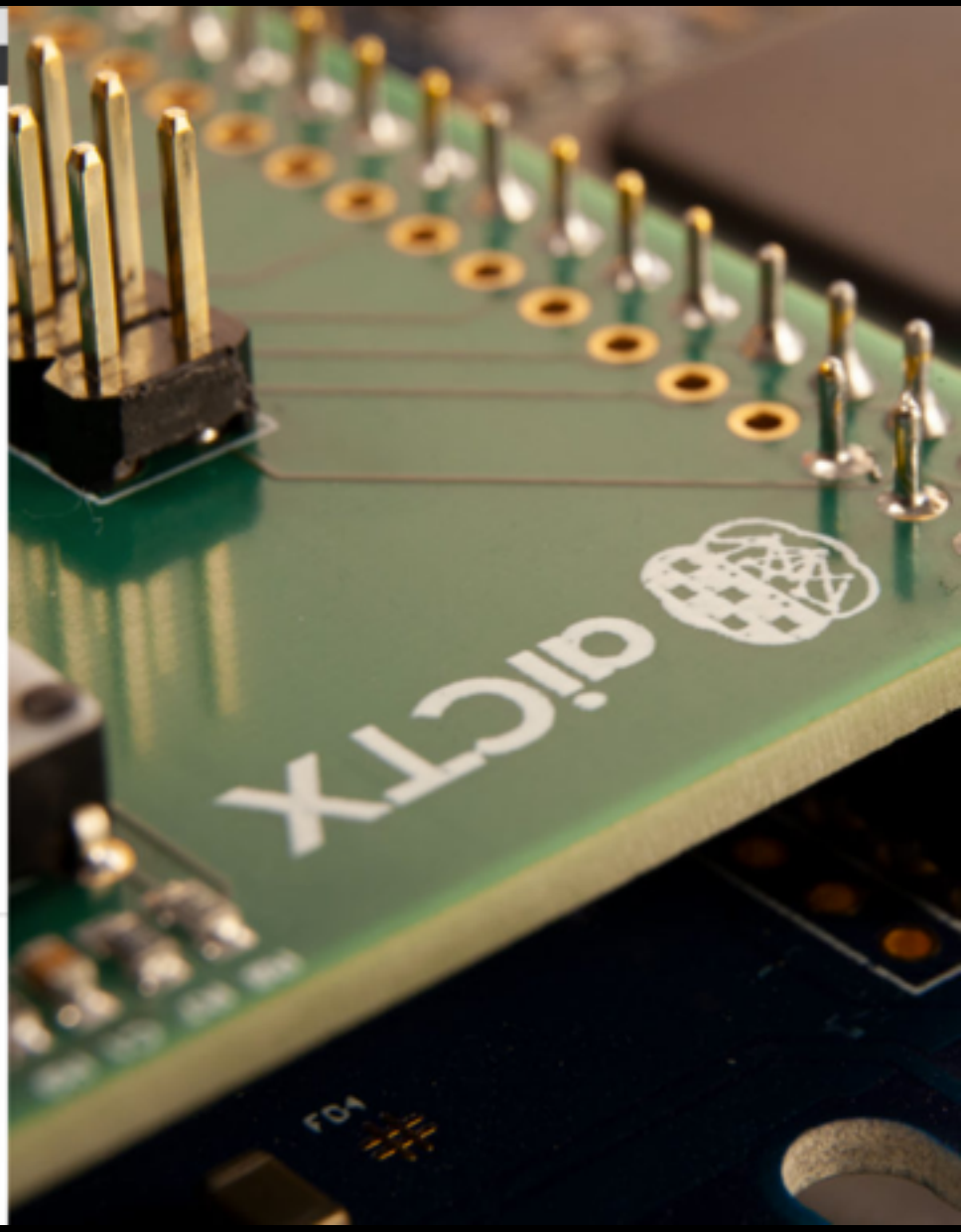


Cortex Control (ctxctl)

- Controller of DYNAP-SE
- Python API
- Remote interface RPYC
- GUI of chip parameters and neuronal activity

https://ai-ctx.gitlab.io/ctxctl/


C0C0
C0C1
C0C2
C0C3
C1C0
IF_AHTAU_N
IF_AHTHR_N
IF_AHW_P
IF_BUF_P
IF_CASC_N
IF_DC_P
IF_NMDA_N
IF_RFR_N
IF_TAU1_N
IF_TAU2_N
IF_THR_N
NPDPIE_TAU_F_P
NPDPIE_TAU_S_P
NPDPIE_THR_F_P
NPDPIE_THR_S_P
>>> import CtxDynapse
>>> model = CtxDynapse.model
>>> biasGroups = model.getBiasGroups()
>>> biasGroups[0].setBias("IF_DC_P", 50,3)
>>> biasGroups[0].setBias("IF_DC_P", 50,2)
>>> biasGroups[0].setBias("IF_DC_P", 50,1)


aiCTX

Now ready to Link Hardware with NeuroML and OSB.

Work in progress

Develop network motifs for:

- Robust computation
- noisy signal processing
- multi sensory fusion

The CapoCaccia Workshops for Neuromorphic Intelligence

http://capocaccia.cc/

- Interdisciplinary, international, diverse
- Morning lectures, afternoon hands-on work-groups
- Active and lively discussions (no powerpoint)
- Concrete results, establishment of long-term collaborations

Capo Caccia, Sardinia, Italy. April 26 - May 9, 2020

Funding Sources

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institute of **neuroinformatics**

A team effort

institute of neuroinformatics

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