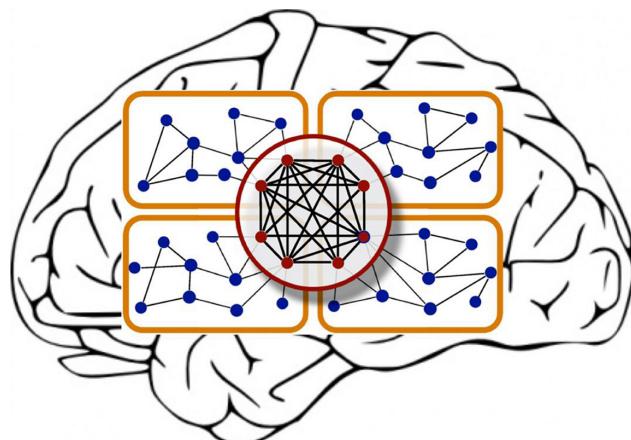


Neuroinformatika



1

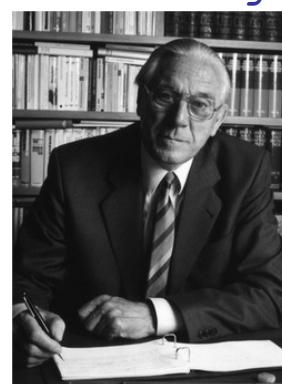
Informatikos termino atsiradimas

Informatik:

Automatische Informationsverarbeitung

Karlas Šteinbuchas

- Vokiečių kibernetikos, inžinierius (Štutgarto, Karlsruės universitetai)
- Pasiūlė terminą
 - *Informatik:*
 - *Automatinis informacijos apdorojimas*



Karl Steinbuch
1917-2005)

2

*Informatik (Vokietija) ≠
Informatics (JK) ≠
Informatics (JAV)*



Vakarų Europoje (išskyrus Jungtinę Karalystę)

Informatika = Computer Science

Jungtinė Karalystė

Informatics – “the study of the structure, algorithms, behavior and interactions of natural and artificial computational systems”
(Edinburgo universitetas)

JAV

Informatics – “the application of information technology to the arts, sciences, and professions” (UC Irvine)

3

M.O. Gewaltig. INCF Workshop, Munich 2012

Neuroinformatika



- 1980m. Vokietijoje ir kitose Europos šalyse
 - Neuroinformatika = dirbtiniai neuroniniai tinklai
 - Dabar: dirbtiniai neuroniniai tinklai – mašininis mokymas
 - 1990m. JAV
 - Neuroinformatika = smegenų duomenų analizė
- Neuroinformatics – computational methods used in neuroscience*

M.O. Gewaltig. INCF Workshop, Munich 2012 4

Neuroinformatika



NEUROINFORMATIKA

[lot. *neuro* – priešdėlis, reiškiantis smegenis, nervus, lot. *informatio* – ...susipažinimas, išaiškinimas, vaizdinys, sąvoka] –

tai mokslas apie gyvūnų neurostruktūrose vykstančius informacinius vyksmus, kodavimą ir dekodavimą, susijusius su gyvūnų atmintimi, aplinkos ir organizmo vidaus savybių atspindėjimu nervų struktūrose, sprendimais veikti, organų bei viso organizmo veiklos ir elgsenos valdymu.

D.Kirvelis, 2009

5

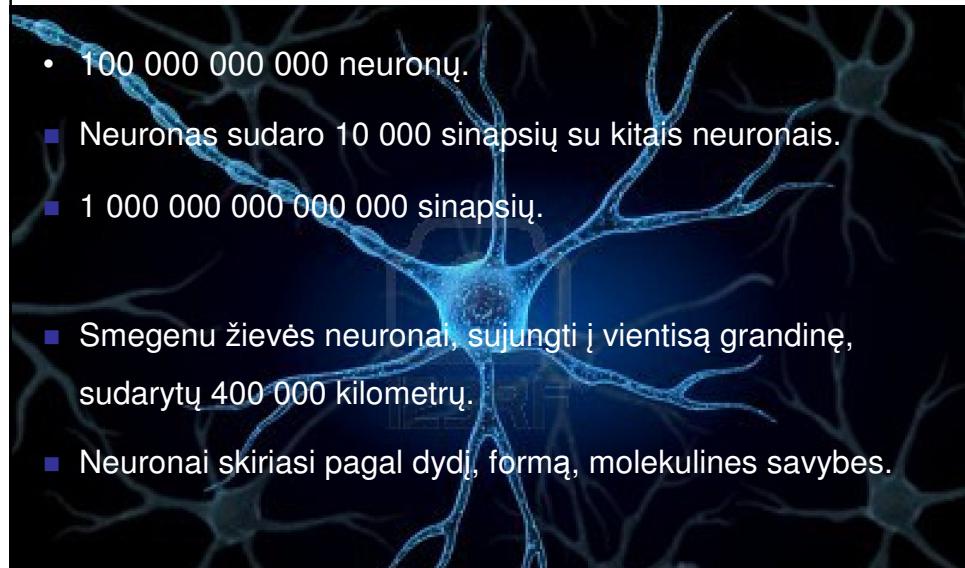
Neuroinformatika

- Duomenų bazės
 - Duomenų saugojimas
 - Duomenų analizė (statistinė, signalų, vaizdų)
 - Duomenų vizualizavimas
- Specializuota programinė įranga
- Matematiniai – kompiuteriniai nervų sistemos modeliai: sudarymas, analizė, taikymas
- Neuroinžinerija (Neuromorphic and neural engineering)

6

Žmogaus smegenų sandaros sudėtingumas

- 100 000 000 000 neuronų.
- Neuronas sudaro 10 000 sinapsių su kitais neuronais.
- 1 000 000 000 000 000 sinapsių.
- Smegenu žievės neuronai, sujungti į vientisą grandinę, sudarytų 400 000 kilometrų.
- Neuronai skiriasi pagal dydį, formą, molekulines savybes.



Neuromokslų iššūkiai

“A grand challenge in neuroscience is to elucidate brain function in relation to its **multiple layers of organization that operate at different spatial and temporal scales**. Central to this effort is tackling “neural choreography” - the integrated functioning of neurons into brain circuits.

Neural choreography **cannot be understood via a purely reductionist approach**.

Rather, it entails the convergent use of analytical and synthetic tools to gather, analyze and mine information from each level of analysis, and capture the emergence of new layers of function (or dysfunction) as we move from studying **genes and proteins, to cells, circuits, thought, and behavior....**

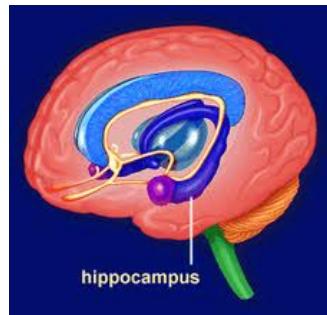
However, the neuroscience community is not yet fully engaged in exploiting the rich array of data currently available, nor is it adequately poised to capitalize on the forthcoming data explosion. “

8

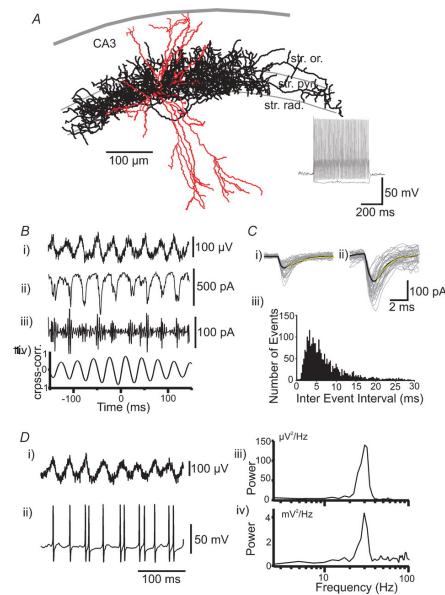
Akil et al., Science, Feb 11, 2011

1. Duomenų bazės

Hipokampus



<http://morphonix.com/software/education/science/brain/game/specimens/hippocampus.html>

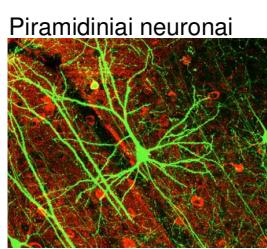


<http://jp.physoc.org/content/562/1/131/F7.expansion>

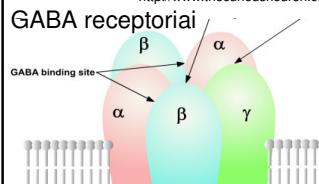
9

Duomenų bazės

Hipokampus



<http://www.thecuriousneuron.com/>



<http://www.biomedcentral.com/1471-2164/8/203/figure/F1?highres=y>

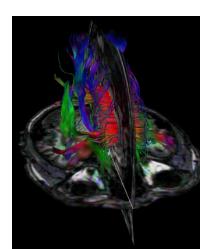


<http://www.med.umich.edu/cdb/people/rigler.html>

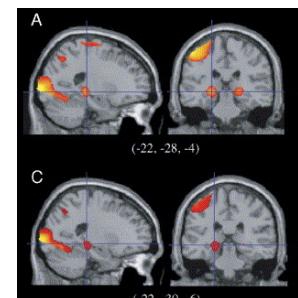
Hipokampus



<http://synapses.cim.utexas.edu/anatomy/hippo/hippo2.htm>



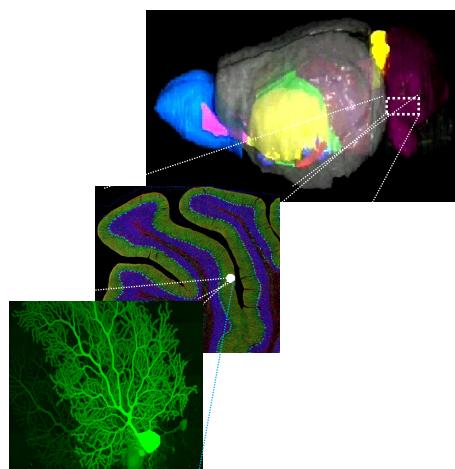
Diffuzinis tenzorių vaizdavimas
<http://www.cimst.ethz.ch/gallery/index>



<http://www.sciencedirect.com/science/article/pii/S1053811906001212>

Duomenų sudėtingumas

Kiekvieną smegenų sritį aprašo įvairaus tipo duomenys.
Būtina duomenis integruoti, lyginti.



Neuroinformatika sieja
procesus molekuliniame,
laistelių, audinio, organo
lygiuose.

11

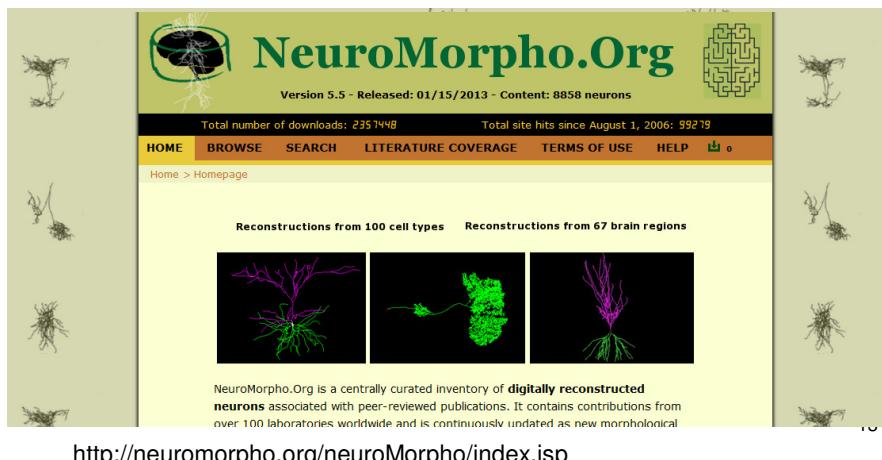
Neuro duomenys

- Neuroinformatikos duomenų bazės:
 - Genai
 - Baltymų makromolekulės (jonų kanalai)
 - Elektrofiziologiniai signalai
 - Vaizdai
 - Gauti skirtingais metodais (MRI, fMRI, PET Positron Emission Tomography, DTI Diffusion Tensor Tomography, EEG, MEG)
 - Cheminiai reagentai apdorotų audinių vaizdai (erdvinė skalė nuo mikronų iki cm)
 - Optiniai įtampos ir cheminių reagentų įrašai
 - Centrinės ir periferinės nervų sistemos atlasai

12

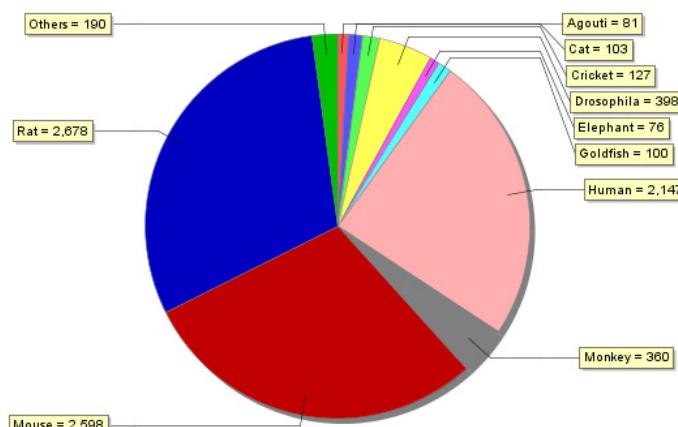
Duomenų bazė NeuroMorpho

- Morfologinė neuronų rekonstrukcija
- Version 5.5 - Released: 01/15/2013 - Content: 8858 neurons, 67 brain regions, contributions from 108 laboratories

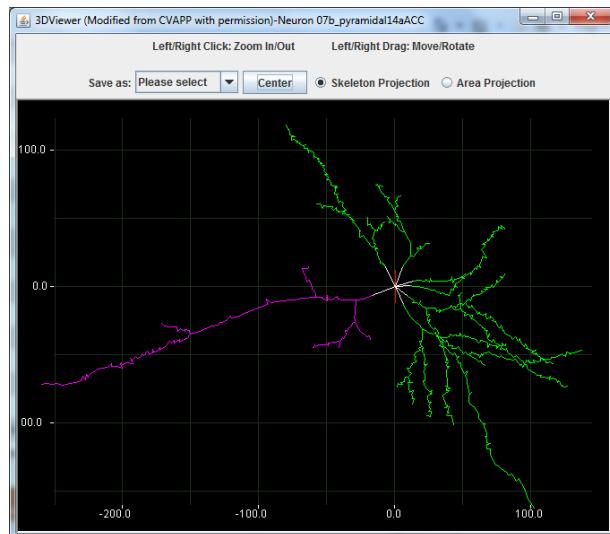


Duomenų bazė NeuroMorpho

- Organizmų rūšys

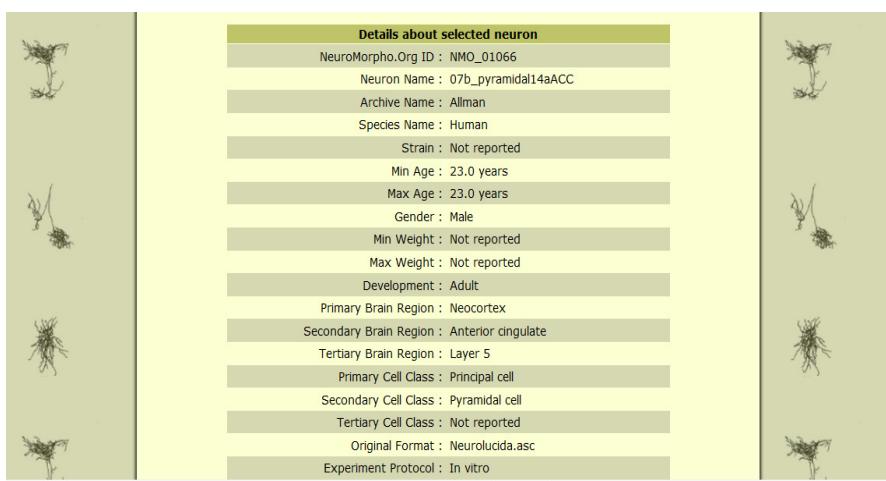


Žmogaus piramidinės neuronas 07b_pyramidal14aACC



15

Žmogaus piramidinės neuronas 07b_pyramidal14aACC



16

Duomenų bazė Channelpedia

- Jonų kanalų duomenų bazė
- 187 jonų kanalų rūšys
- Introduction, Genes, Ontologies, Interactions, Structure, Expression, Distribution, Function, Kinetics and Models.

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

BLUE BRAIN PROJECT

CHANNELPEDIA

EPFL > FSV > BBR > Channelpedia

User

ION CHANNELS

Ion channels ▾

- ▀ K
- ▀ Na
- ▀ Ca
- ▀ Cl
- ▀ Ih
- ▀ TRP
- ▀ A
- ▀ Priority

REFERENCES

REPORTS

SEARCH IN WIKI

About

Channelpedia is an information management framework for comprehensive ion channel information. It is a knowledge base system centered on genetically expressed ion channel models and it encourages researchers of the field to contribute, build and refine the information through an interactive wiki-like interface. It is web-based, freely accessible and currently contains 187 annotated ion channels with 50 Hodgkin-Huxley models.

Channelpedia provides an ideal platform to collectively build ion channel knowledge base by accommodating both structured and unstructured data. The current version of Channelpedia contains the following sections : Introduction, Genes, Ontologies, Interactions, Structure, Expression, Distribution, Function, Kinetics and Models.

Newly published literature related to ion channels is automatically queried every week

Unstructured data
Wiki like user editable section. User can upload data files, images with description and appropriate references[1].
Edit | History

Structured data

ID	Name	Description
Link1	Item1	Description1

Discussion and synthesis

User1
User2

Ih(HCN) is known to be distributed exponentially on pyramidal cells [3];
User2

Cell	Param 1	Param n
LSPC	A	B

Internet | Protected Mode: On

<http://channelpedia.epfl.ch/>

CHANNELPEDIA

Kv1.2

Unstructured data

Introduction

Potassium voltage-gated channel subfamily A member 2 also known as Kv1.2 is a protein that in humans is encoded by the KCNA2 gene.

Genes

RGD ID	Chromosome	Position	Species
2950	2	202560152-202564305	Rat
10830	3	106904485-106909797	Mouse
735518	1	111145776-111148245	Human

Structured data

Models

Hodgkin-Huxley model

Animal	CellType	Age	Temperature	Reversal	Ion	Ligand ion	Ref	mpower	mInf	mTau	hpover	hInf	hTau
rat	Oocyte	0 Days	20.0°C	-65.0 mV	K +		Sprung L K et.al; Eur. J. Pharmacol. 1996 Oct 31	1.0	1.000/(1+ exp((v -21.000)/-11.3943))	150.000/(1+ exp((v -67.5600)/34.1479))	1.0	1.000/(1+ exp((v -22.000)/11.3943))	15000.000/(1+ exp((v -46.5600)/-44.1479))

Navigation

IC Families

- ▀ Expand all
- ▀ Collapse all
- ▀ K
 - ▀ Kv1
 - ▀ Kv2
 - ▀ Kv2.1
 - ▀ Kv2.2
 - ▀ Kv3
 - ▀ Kv4
 - ▀ Kv5
 - ▀ Kv6
 - ▀ Kv7
 - ▀ Kv8
 - ▀ Kv9
 - ▀ Kv10
 - ▀ Kv11
 - ▀ Kv12
 - ▀ Kir
 - ▀ KCNQ
 - ▀ KCa
 - ▀ KvG
- ▀ Na
- ▀ Ca
- ▀ Cl
- ▀ Ih
- ▀ A
- ▀ M
- ▀ TRP

REFERENCES

REPORTS

SEARCH IN WIKI

References

[1] An activation gating switch in Kv1.2 is localized to a threonine residue in the S2-S3 linker. [2] Biophys. J., 2007 Dec 15, 93(4):173-86. Download

[2] The glycosylation state of Kv1.2 potassium channels affects trafficking, gating, and simulated action potentials. [3] Brain Res., 2007 May 4, 1144(1-18). Download

[3] Inhibition by bis(7)-tacrine of native delayed rectifier and KV1.2 encoded potassium channels. [4] Neurosci. Lett., 2007 Jan 29, 412(108-13). Download

Reference management

MOD xml

<http://channelpedia.epfl.ch/Kv1.2>



INCF tinklapis

www.incf.org

INCF International Neuroinformatics Coordinating Facility

Sitewide search

Find any software, resource, person, article etc.

Sign in >
or [register](#) an account

Neuroinformatics integrates many kinds of data - from genes to behavior - to help understand the brain and its disorders

LEARN MORE

Sitewide search

Find any software, resource, person, article etc.

Sign in >
or [register](#) an account

INCF coordinates collaborative **neuroinformatics infrastructure** and promotes the sharing of **data** and **computing resources** to the international research community

LEARN MORE

[What we do](#)

INCF Software Center

- INCF Software Center – programinė įranga, skirta neuromokslams

The screenshot shows the main landing page of the INCF Software Center. At the top right is a "LOG IN REGISTER" button and a world map icon. Below the header is a navigation bar with "ABOUT", "BROWSE SOFTWARE", and "REGISTER SOFTWARE" buttons, along with a "Search Site" input field. The main content area has three main sections: "INCF SOFTWARE CENTER" (listing recent software releases like "Linked Neuron Data" and "cochlea"), "BECOME A MEMBER" (describing the process), and "SEARCH SOFTWARE" (with a search bar and a link to browse all software). The URL http://software.incf.org/ is visible at the bottom.

INCF Software Center

The Virtual Brain



LOG IN | REGISTER

You are here: Home → Browse Software → The Virtual Brain (TVB)

The Virtual Brain (TVB)

Overview

Downloads & Documentation

Screenshots

Team

Search Site

TVB is a platform for whole brain network simulations, enabling the model-based generation of neuroimaging signals such as fMRI, EEG and MEG.

Purpose

The choice to develop a research tool directly focused on mesoscopic models of neural dynamics implemented at the scale of the whole primate brain comes from practical considerations about computational feasibility and the fact that the most common experimental neuroimaging modalities (EEG, MEG, fMRI) in humans record on the macroscopic scale. EEG and MEG, by their nature, record a summation of neural activity from a large portion of the human brain, likewise fMRI, although recording localised changes, measures processes that operate on a much larger scale than single neurons and is typically used to record the activity of most if not all of a subject or patient's brain. It then seems natural to produce commensurate models of neural activity, ideally incorporating the spatial structure, such as the folded cortical surface and long-range myelinated fibre connections, which can be extracted from experimental data and provides an explicit constraint on source geometries.



THE VIRTUAL BRAIN.

Topics

Large scale modeling
Clinical neuroscience
Neuroimaging
Computational neuroscience

Keywords

Visualization, MEG, Stimulus Presentation, Forward - Inverse, Python, MEG Modeling, Database, Modelling, Simulation, EEG Modeling, Network model, GPU, EEG, Developers, Data, GNU General Public License (GPL).

Contact person

Lia Domide

Paula Sanz Leon

Members

Lia Domide

Paula Sanz Leon

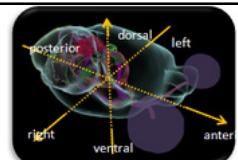
INCF Data Space

- INCF Data Space – erdvė įvairaus formato duomenims: neuro eksperimentų įrašams, tekstiniams failams, vaizdams, garso signalams, video, modeliams.

The screenshot shows the INCF Dataspace homepage. On the left, there's a large graphic with the text "Do you want to...?" and four circular icons: "...discover neuroscience data?", "...share your existing large dataset?", "...make your data visible globally?", and "...make your data visible to collaborators?". On the right, there's a "GET STARTED!" section with "LOG IN" and "SIGN UP" buttons, and a note about "FREE CREDITS AVAILABLE!" from "amazon web services™". The URL <http://incf.org/resources/data-space> is at the bottom left of the screenshot area.

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INCF Programa Digital Brain Atlasing



Tikslas: koordinuoti smegenų atlasų kūrimą (standartizavimas, palyginimas, apjungimas)

Projektai:

Scalable Brain Atlas

Waxholm Space (WHS)

Scalable Brain Atlas

The Scalable Brain Atlas (SBA) is a fully web-based display engine for brain atlases, imaging data and topologies. It allows client websites to show brain region related data in a 3D interactive context and provides services to look up regions, generate thumbnails or download nomenclature- and delineation data.

Macaque atlases



The [Paxinos Rhesus Monkey atlas \(2000\)](#)

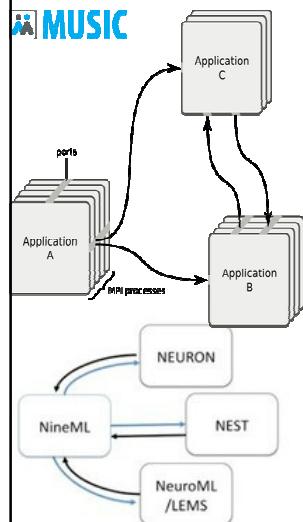
Various templates available through [Caret](#), registered to F99 space:

- Felleman and Van Essen (1991)
- Lewis and Van Essen (2000)
- Regional Map from Kotter and Wanke (2005)
- Paxinos Rhesus Monkey (2000)
- Markov, Misery et al. (2011)

<http://scalablebrainatlas.incf.org/main/index.php>

24

INCF Programa MUSICS, NineML



Tikslas: sukurti programinę įrangą daugiaskaliams neuronų ir neuronų struktūrų modeliavimui.

Produktai ir paslaugos:

MULTI-Simulation Coordinator

(MUSIC)

Network Interchange for Neuroscience Markup Language
(NineML)

MUSIC: programinė įranga, leidžianti programiniams paketams keistis informacija simuliacijų/eksperimentų metu.

NineML: formali modelių aprašymo kalba,
nepriklausanti nuo programinio paketo

25

<http://software.incf.org/software/nineml>

NEURON ModelDB Modelių duomenų bazė

ModelDB provides an accessible location for storing and efficiently retrieving computational neuroscience models. ModelDB is tightly coupled with [NeuronDB](#). Models can be coded in any language for any environment. Model code can be viewed before downloading and browsers can be set to auto-launch the models. For further information, see also, [model sharing in general](#) and [ModelDB in particular](#).

Submit a new model entry Model entry tutorial Help

Find models by

- Model name
- First author
- Each author
- Region(circuits)

Find models for

- Networks
- Cell type
- Current
- Receptor
- Gene
- Transmitters
- Topic
- Simulators
- Methods

Find models of

- Networks
- Neurons
- Electrical synapses (gap junctions)
- Chemical synapses
- Ion channels
- Neuromuscular junctions
- Axons

• <https://senselab.med.yale.edu/modeldb/>

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2. Specializuota programinė įranga

27

Programinės įrangos svarba



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

SCIENTIFIC PUBLISHING

A Scientist's Nightmare: Software Problem Leads to Five Retractions

Until recently Geoffrey Chang's career was on a trajectory most young scientists only dream about. He had published several papers, won grants, and was invited to speak at international conferences. Then, in 2001, he got a job as a Whitehead Fellow at the California Institute of Technology's Division of Science and Engineering, the equivalent of a postdoctoral researcher. His lab generated a series of papers detailing the molecular structures of important proteins embedded in membranes.

Then the trouble started. In a single year, six papers published by Chang and his colleagues retracted three. "I was horrified," says Chang, who investigated what went wrong. When he investigated, Chang was horrified to discover that a program he had used to analyze data had flipped two columns of data, inverting the electron-density map from which his team had derived the final protein structure. Unfortunately, no paper had noted the problem in its caption.

As a result, on page 1873, Chang and his colleagues retract three Science publications, all of which have been retracted. "I'm very sorry for the inconvenience," Chang says. "It was unfortunate, and although some say it has cost them time and money, I think it has been a valuable lesson for me and my group." In fact, Chang has since coauthored a paper titled "Lessons from our experience about biological structure determination by X-ray crystallography and electron microscopy and their application to membrane protein structure determination," according to Google Scholar.

Chang's work has been cited more than 100 times, according to Google Scholar.

In addition, other researchers cite his work in their publications, further extending Chang's influence.

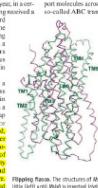


Figure 1. MsbA transporter structure.

The consequences of faulty software

From the EPFL website:

On page 1873 of the December 22 issue of *Science*, Chang et al. describe the structure of MsbA, a membrane protein involved in drug resistance.

On page 1856 of the same issue, Miller et al. describe the structure of MsbA.

Both papers were published in 2005.

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Both papers were retracted in 20218.

Both papers were retracted in 20219.

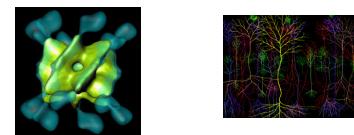
Both papers were retracted in 20220.

Both papers were retracted in 20221.

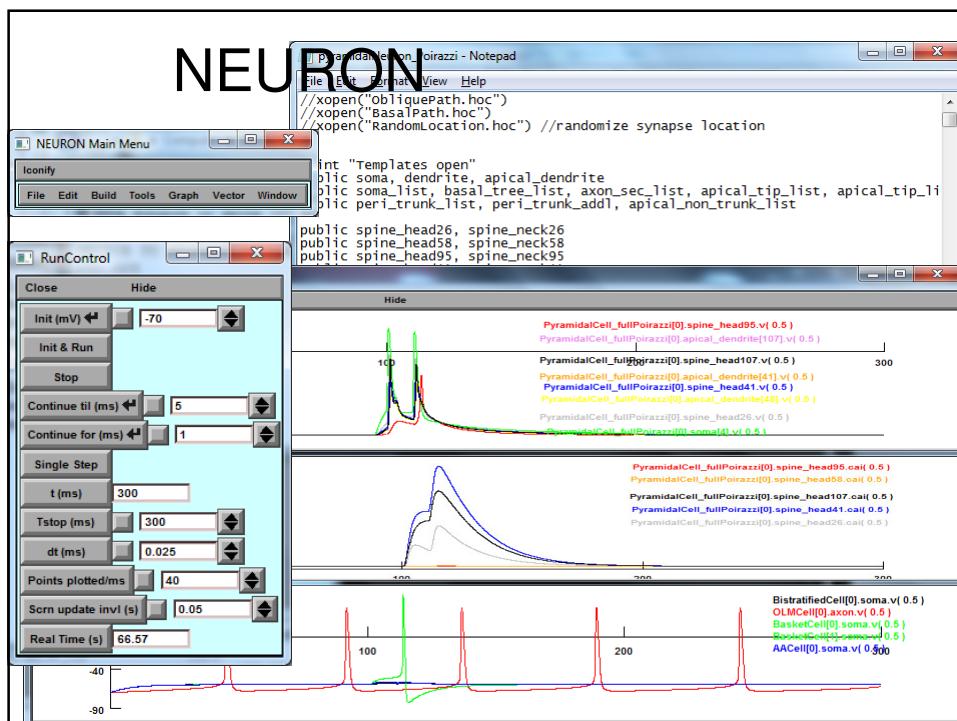
Both papers were re

Programinė įranga

- NEURON
- GENESIS
- NEST – Neural Simulation Tool
 - Galima modeliuoti 100 000 neuronų
- BRIAN
- MOOSE - Multiscale object-oriented simulation environment
 - Elektrinių ir cheminių įvykių modeliavimas
 - plačioje laiko ir erdvės dimensijų skalėje



29



NEURON

Programinis paketas, skirtas biologinių neuronų ir jų tinklų modeliavimui

<http://www.neuron.yale.edu/neuron>

31

GENESIS

- GEneral NEural SImulation System

<http://genesis-sim.org/>

32

NEST

Programinis paketas, skirtas dideliems neuronų tinklams modeliuoti

The screenshot shows the NEST initiative website. The header features the 'nest:: initiative' logo. The left sidebar contains links for 'NEST Software' (About NEST, Download, Features, Documentation, Publications, Community, Reporting bugs) and 'NEST Initiative' (About us, Membership, Activities, Contact). The main content area is titled 'Software:About NEST'. It includes a 'Contents [hide]' sidebar with links to 'What is NEST?', 'How do I use NEST?', 'Why should I use NEST?', 'Please cite NEST and tell us about your work', 'NEST logo for your poster or presentation', and 'System requirements'. The main text area starts with 'What is NEST?'. It describes NEST as a simulator for spiking neural network models that focus on dynamics, size, and structure of neural systems rather than exact morphology of individual neurons. It states that NEST is ideal for networks of spiking neurons of any size, for example, models of information processing in the visual or auditory cortex of mammals.

http://www.nest-initiative.org/index.php/Software:About_NEST

33

BRIAN

Programinis paketas, skirtas dideliems neuronų tinklams modeliuoti

The screenshot shows the BRIAN simulator website. The header features the 'BRIAN' logo. The main content area is titled 'Network of sparsely connected inhibitory integrate-and-fire neurons'. It includes a brief description: 'Dynamics of a network of sparsely connected inhibitory integrate-and-fire neurons. Individual neurons fire irregularly at low rate but the network is in an oscillatory global activity regime where neurons are weakly synchronized.' Below this is a reference: 'Reference: Brunel N, Hakim V, Fast Global Oscillations in Networks of Integrate-and-Fire Neurons with Low Firing Rates, Neural Computation 11, 1621–1671 (1999)'. To the left is a code snippet for creating the network:

```

1 #! /usr/bin/env python
2 # Network parameters
3 N = 5000
4 Vinit = -65 * mV
5 theta = 20 * mV
6 tau = 20 * ms
7 C = 100 * pA
8 taurefr = 2 * ms
9 duration = 1.1 * second
10 tstop = 1000 * ms
11 sparseness = float(C)/N
12 weight = 0.05 * mV
13 must = 25 * mV
14 sigmaext = 1 * mV
15 eqs = "dv/dt=(-V-must+sigmext*sqrt(tau)*xi)/tau : volt"
16 group = NeuronGroup(N, eqs, threshold=theta,
17                     refractory=taurefr)
18 group.V = Vr
19 # Connections
20 conn = Connection(group, group, state='V', delay=delta,
21                   weight=-J, sparseness=sparseness)
22 # Monitors
23 M = SpikeMonitor(group)
24 # Run
25 run(1000*ms)

```

To the right is a plot showing the firing patterns of 5000 neurons over time, with spikes represented by blue dots. The y-axis is labeled 'Neuron number' and ranges from 1000 to 5000. The x-axis represents time. The plot shows periodic bursts of activity across all neurons.

<http://briansimulator.org>

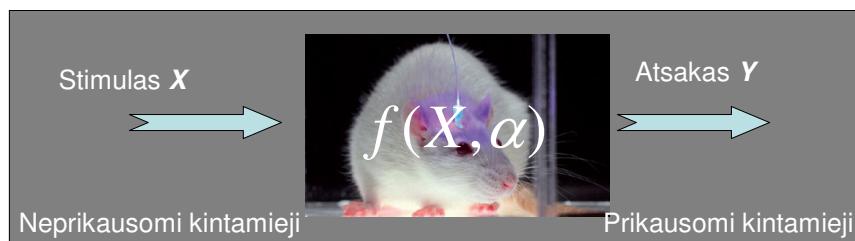
3. Nervų sistemos modeliai

- Kas yra modelis?



35

Matematinio modelio apibrėžimas



- Modelis – tai funkcija $Y=f(X, \alpha)$
 α - parametrai
- Modeliai sudėtingi

36

Nervų sistemos modeliai

- Matematinis neurono modelis

$$\begin{aligned}C \frac{dv}{dt} &= I - g_{Na}m^3h(V - V_{Na}) - g_Kn^4(V - V_K) - g_L(V - V_L) \\ \frac{dm}{dt} &= a_m(V)(1 - m) - b_m(V)m \\ \frac{dh}{dt} &= a_h(V)(1 - h) - b_h(V)h \\ \frac{dn}{dt} &= a_n(V)(1 - n) - b_n(V)n \\ a_m(V) &= .1(V + 40)/(1 - \exp(-(V + 40)/10)) \\ b_m(V) &= 4 \exp(-(V + 65)/18) \\ a_h(V) &= .07 \exp(-(V + 65)/20) \\ b_h(V) &= 1/(1 + \exp(-(V + 35)/10)) \\ a_n(V) &= .01(V + 55)/(1 - \exp(-(V + 55)/10)) \\ b_n(V) &= .125 \exp(-(V + 65)/80)\end{aligned}$$

<http://www.math.pitt.edu/~bard/bardware/tut/newstyle.html> 37

Modeliavimo privalumai

Modeliai gali būti suprantami kaip duomenų bazės,
nes apjungia eksperimentinius duomenis.

Modeliai leidžia suprasti sistemos dinamiką, sąveiką
su kitomis sistemomis, nustatyti esminius
parametrus, jų įtaką.

Modeliai naudingi planuojant eksperimentus.

Modeliai yra pigesni nei fiziologiniai eksperimentai

Modeliavimo žingsniai

1. Hipotezės iškėlimas
2. Duomenų surinkimas
3. Sistemos aprašymas
4. Sistemos įgyvendinimas
5. Kompiuterinių eksperimentų atlikimas, modelio validavimas
6. Modelio taikymas prognozēms
7. Rezultatų analizė, išvados

39

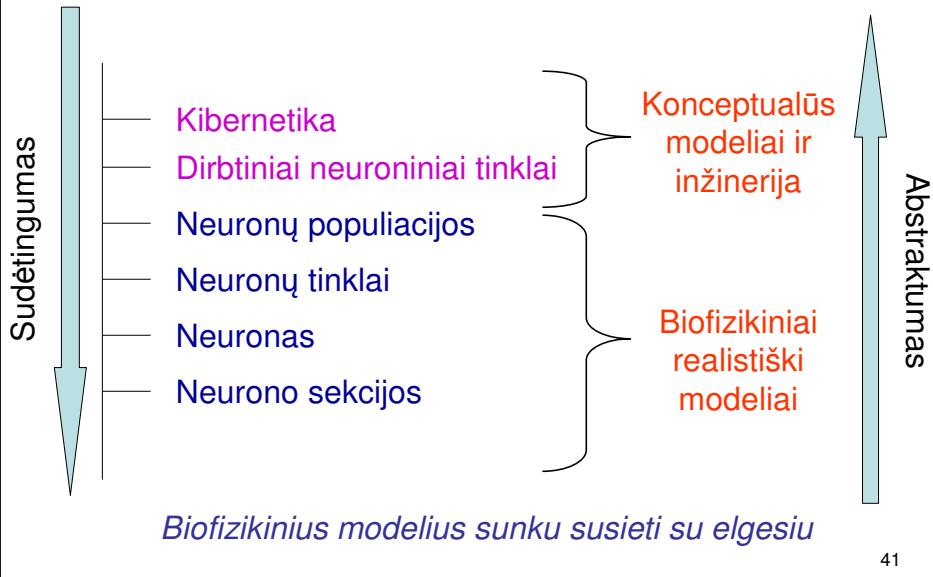
Nervų sistema: sandaros lygmenys



CNS	1m	(elgesys)
Grandinės tarp sričių	10cm	(tinklainė, hipokampus)
Lokalinės grandinės	1cm	(ritmo generavimas)
Neuronai	100µm	(veikimo potencialai)
Dendritiniai medžiai	10µm	(dendritiniai skaičiavimai)
Mikrograndinėlės	1µm	(sinapsių tarpusavio poveikis)
Sinapsės	1µm	(žadinančios, slopinančios)
Molekulės ir jonai	0.1µm	(proteinų makromolekulės – kanalai, Na, K, Ca jonai)

40

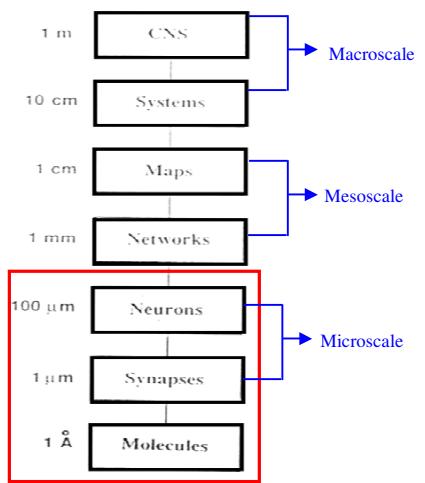
Neuronai: modeliavimo lygmenys



Computational Neuroscience

Neuronų mikrograndinių modeliai

Vieno neurono ir molekulinių sąveikų neurone modeliai



- Atmintis
- Mokymasis
- Vystymasis
- Sensorinės informacijos apdorojimas
- Neurologinės ir psichikos ligos

■ Makroskalė: smegenų sritys, sujungtos aksonų pluoštais

■ Mezoskalė: neuronų tinklai, jungiantys neuronų populiacijas (pvz., smegenų žievės mikrokolonėles)

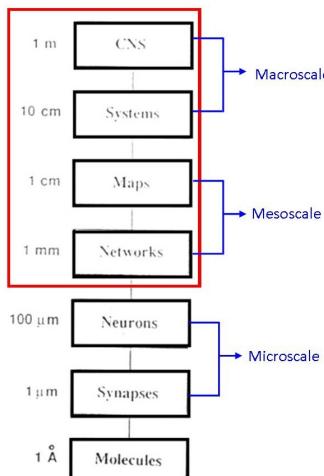
42

■ Mikroskalė: sinapsės, mikrograndinėlės

Cognitive Neuroscience

Kognityvinių funkcijų neuroniniai modeliai

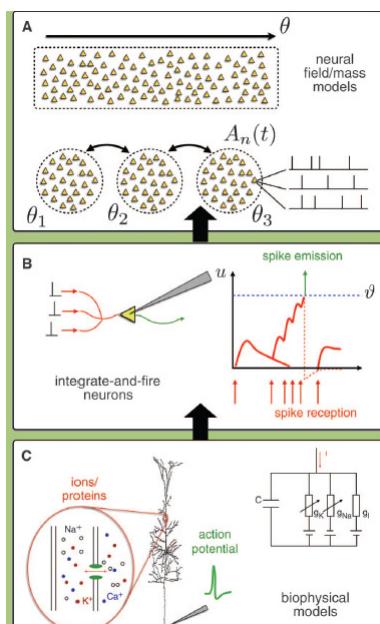
Neural system levels that are modeled as networks



- Atmintis
- Mokymasis
- Dėmesys
- Sprendimų priėmimas
- Veidrodiniai neuronai
- Kalba
- Emocijos
- Sąmonė

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Bottom-up modeliavimo principas



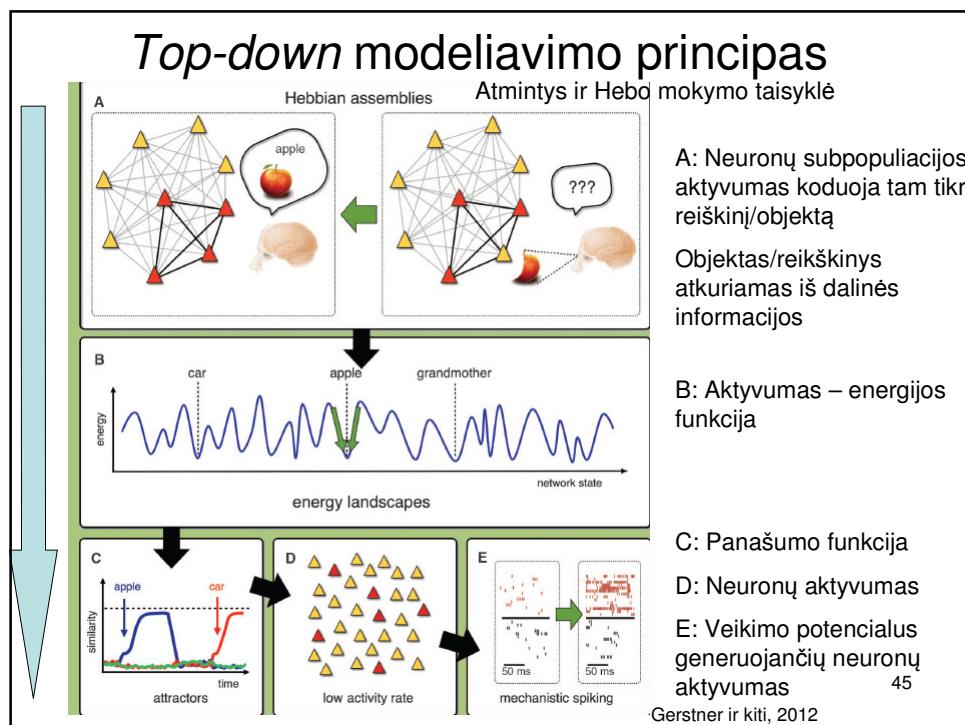
Neuronų populiacija

Supaprastintas neurono modelis (Integrated-and-fire)

Biofizikinis neurono modelis

44

Gerstner ir kiti, 2012



Modeliavimo principai

- Bottom-up: nuo neuronų prie funkcijų
- Top-down: nuo kognityvinių funkcijų prie neuronų tinklų ir neuronų

Modelių tipai

- Fenomenologiniai (supaprastinti)
- Biofizikiniai (detalūs, realistiški)

46

Du modeliavimo metodai

1. Analitinis

- tikslūs matematiniai skaičiavimai

2. Kompiuterinis

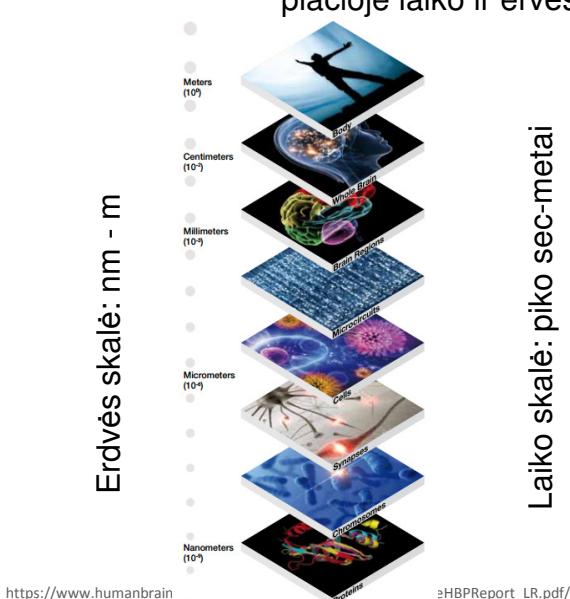
- sistema aprašančių lygčių sprendimas skaitmeniniais metodais
 - Naudingas, kai sistema sudėtinga, analitiniai sprendiniai negalimi
 - Paremtas lygtimis, dažniausiai diferencialinėmis

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Daugiaskalinis modeliavimas (*Multiscale modeling*)

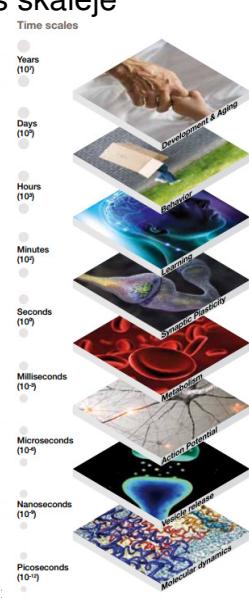
Neuro duomenų analizė, integravimas, modeliavimas
plačioje laiko ir ervės skalėje

Erdvės skalė: nm - m



<https://www.humanbrain>

Laiko skalė: pikto sec-metai



eHBPReport_LR.pdf/

48

55

The Human Brain Project 2013 - 2023

- Žmogaus smegenų matematinis-kompiuterinis modeliavimas panaudojant IBM superkompiuterius
- Tikslas - suprasti smegenų struktūrą ir funkcijas



Supercomputers, Human Brain project

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The Human Brain project 2013-2023 Tyrimų kryptys

- Ateities neuromokslai
 - Matematiniai smegenų modeliai
- Ateities medicina
 - Ligų gilesnis supratimas
- Ateities technologijos
 - Efektyvūs algoritmai ir elektroninės sistemos



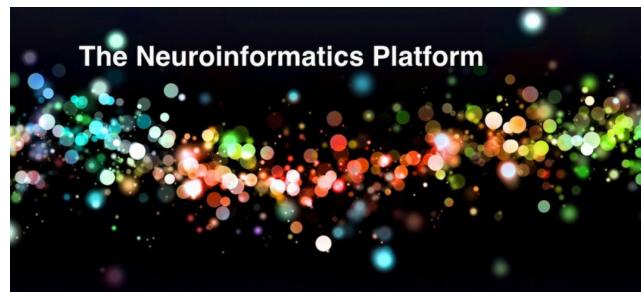
50

<https://www.youtube.com/watch?v=JqMpGrM5ECo>

50

Neuroinformatics Platform

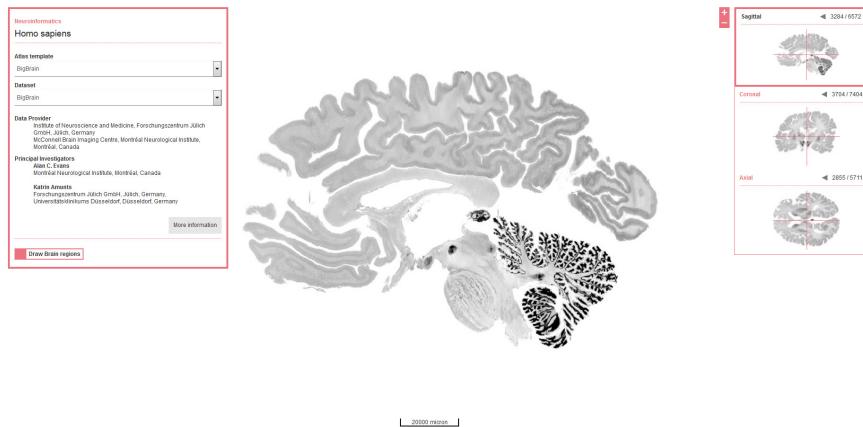
- The Neuroinformatics Platform serves as the Human Brain Project's search engine for distributed data, curated data repositories, brain atlases and knowledge about the brain.
- <https://nip.humanbrainproject.eu/>



51

Homo sapiens Brain Atlas

<https://nip.humanbrainproject.eu/atlas/#/>



High Performance and Computing Platform

- The High Performance Analytics and Computing (HPAC) Platform provides neuroscientists with the high performance computing (HPC), storage and data processing capabilities they need to run simulation of sophisticated, detailed brain models and to analyse large, complex data sets. It also provides software tools and frameworks.



Capabilities

The High Performance Analytics & Computing Platform comprises supercomputing capabilities at Forschungszentrum Jülich (Germany), the Swiss National Supercomputing Centre (CSCS) in Lugano, the Barcelona Supercomputing Center (BSC, Spain), and the Consorzio Interuniversitario del Nord Est italiano per il Calcolo Automatico (CINECA, Italy) in Bologna.

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Brain Simulation Platform

- It aims at providing scientists with powerful tools to reconstruct and simulate scaffold models of brain and brain tissue in a data-driven fashion.
- Hippocampus
- <https://collab.humanbrainproject.eu/#/collab/161/nav/5575>



54

Medical Informatics Platform

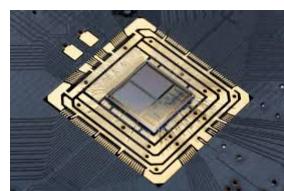
- The aim of the Medical Informatics Platform is to provide researchers the ability to access and analyse large amounts of anonymised clinical data from hospital, research, and pharmaceutical clinical trial databases through an innovative data management system that we are building.



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Neuromorphic Computing Platform

- The Neuromorphic Computing Platform developed in the Human Brain Project (HBP) provides remote access to two complementary, large-scale neuromorphic computing systems (NCS) built in custom hardware at locations in Heidelberg (the BrainScaleS system) and Manchester (the SpiNNaker system).

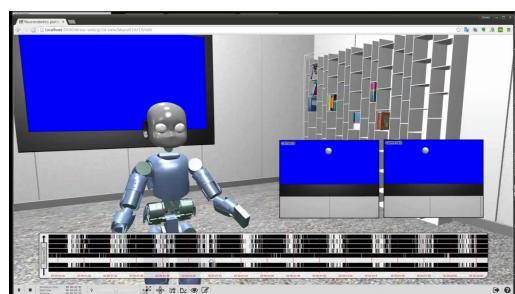


- The BrainScaleS system: 20 wafers, each: 50×10^6 plastic synapses, 200,000 biologically realistic neurons.
- The SpiNNaker system: 30,000 custom digital chips, each can simulate 16,000 neurons with eight million plastic synapses

56

Neurorobotics Platform

- The NeuroRobotics Platform (NRP) is an Internet-accessible simulation system that allows the simulation of robots controlled by spiking neural networks.
- <https://collab.humanbrainproject.eu/#/collab/71/nav/11717>



57

A Virtual Universe

NATURE | NEWS



Model Universe recreates evolution of the cosmos

Successful simulation lends weight to standard model of cosmology.

Elizabeth Gibney

07 May 2014



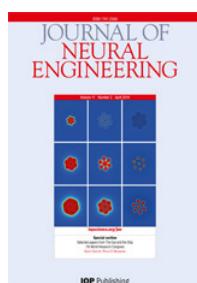
<https://www.youtube.com/watch?v=SY0bKE10ZDM>

58

4. Neuroinžinerija ir neuromorfinės sistemos

Neuroinžinerija siekia sukurti dirbtines inžinerines sistemas, kurios leistų suprasti, atkurti, pakeisti biologinių neuroninių sistemų funkcijas.

Apima biologijos, fizikos, matematikos, informatikos, inžinerijos sritis.

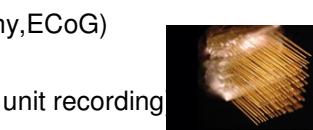
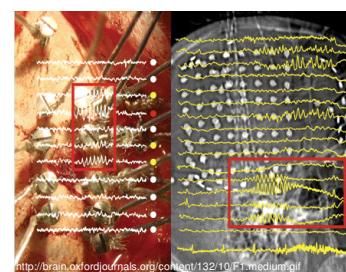


A brain-computer interface for controlling an exoskeleton

[59
http://iopscience.iop.org/1741-2552/](http://iopscience.iop.org/1741-2552/) <https://www.youtube.com/watch?v=jeLghZ8GASA>

Smegenų-kompiuterio sąsaja *Brain-Machine Interface (BMI)*

- Smegenų-kompiuterio sąsaja - sistema, kuri nuskaito ir analizuoją smegenų aktyvumo signalus bei perduoda juos kompiuteriniams prietaisams ar neuroprotezams valdyti.
- Metodai smegenų signalams nuskaityti:
 - Neinvaziniai metodai:
 - Elektroencefalografija (EEG),
 - Magnetoencefalografija (MEG)
 - Magnetinis ir funkcinis magnetinis rezonansas (MRI, fMRI)
 - Invaziniai metodai:
 - Elektrokortikografija (Electrocorticography, ECoG)
 - Smegenų masyvai (Brain arrays)
 - Neuronų aktyvumo nuskaitymas (Single unit recording)

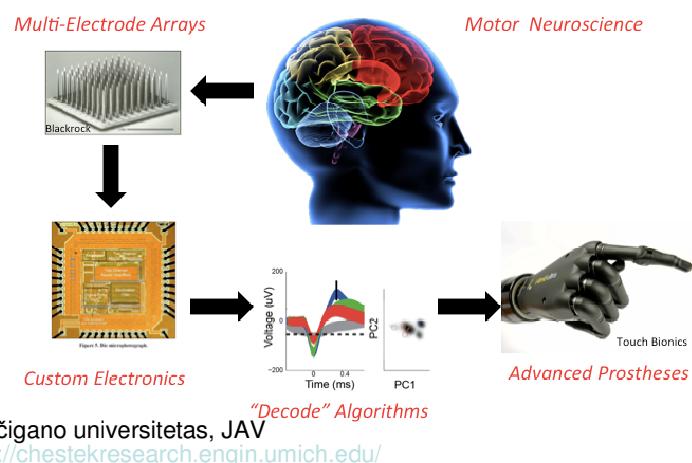


60

<http://www.brainfacts.org/about-neuroscience/technologies/articles/2011/brain-machine-interface/>

Smegenų – kompiuterio sasaja neuroprotezams valdyti

Neuroprotezai – dirbtiniai prietaisai, valdomi smegenų ar periferinių nervų signalais ir pakeičiantys nefunkcionaljančias biologinės sistemos dalis.



Mintimis valdoma ranka

- Žmogaus smegenų signalai perduodami dirbtinei rankai



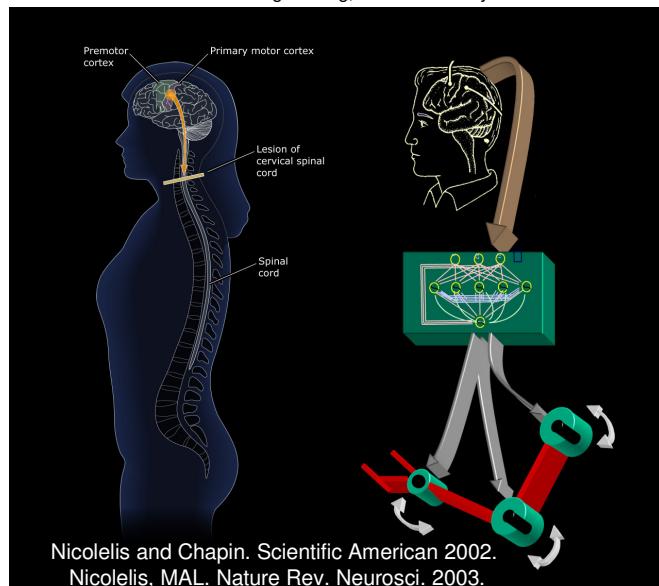
https://www.youtube.com/watch?v=AB5vYz1-T_Y

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Cortical Neuroprosthesis for Restoring Motor Functions

Miguel A. L. Nicolelis

Depts. Neurobiology and Biomedical Engineering,
Center for Neuroengineering, Duke University



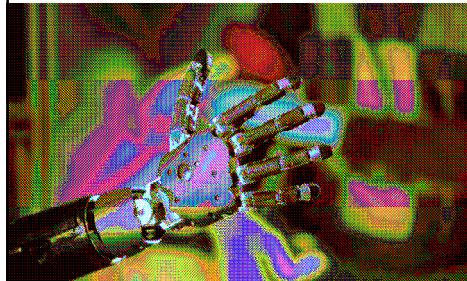
Nicolelis and Chapin. Scientific American 2002.
Nicolelis, MAL. Nature Rev. Neurosci. 2003.

NEUROENGINEERING

Mind in Motion

The idea that paralyzed people might one day control their limbs just by thinking is no longer a Hollywood-style fantasy

By Miguel A. L. Nicolelis



2014 CYBORG OPENING KICK

The Nicolelis lab intends to provide an exoskeleton for a handicapped teenager to make the first kick of the opening event of the World Cup in Brazil.

12 June 2014 Last updated at 19:57 GMT

Share

Paraplegic in robotic suit kicks off World Cup

By Alejandra Martins and Paul Rincon
BBC news staff



Scientific American, September 2012

www.sciencemag.org SCIENCE VOL 338 21 DECEMBER 2012

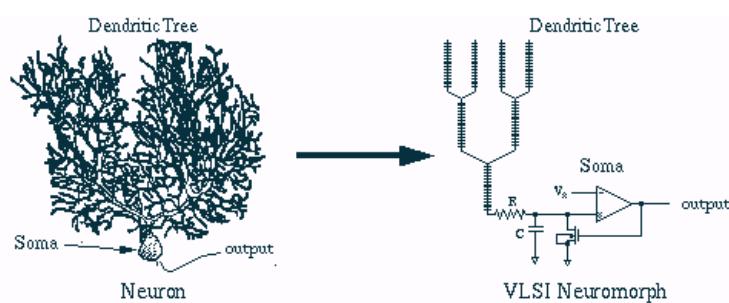


Neuromorfinės sistemos

Neuromorfinės sistemos – dirbtinės neuroninės sistemos, pagamintos naudojant silicio technologijas.

Funkcionavimo principai yra pagrįsti dėsniais, stebimais biologinėse neuro sistemose.

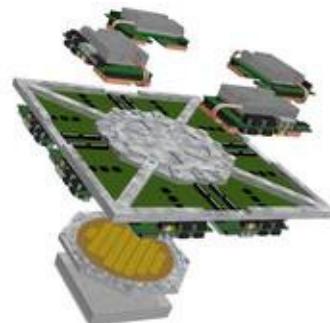
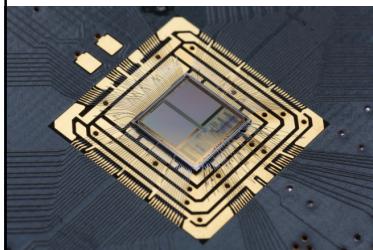
Pasižymi dideliu veikimo sparta ir mažu sunaudojamomis energijos kiekiu.



<https://www.eecis.udel.edu/~elias/neuromorphicSystems/>

66

Spikey neuromorfinė sistema The Human Brain Project



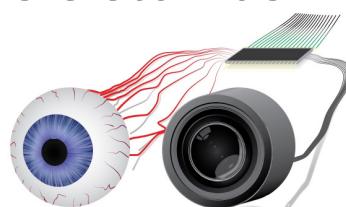
Heidelbergo universitetas, Vokietija

67

Neuromorfinės sistemos

• Neuromorfinės sistemos:

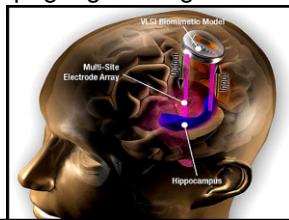
- Smegenų implantai
- Dirbtinė regos sistema
- Garsų analizės sistema
- Autonominiai robotai



<http://neuromorphs.net/nm/wiki/2014/map14>

• Išmanieji sensoriai:

- Objektų judesio detektoriai
- Objektų buvimo detektoriai
- Objekto vienos nustatymas pagal garo signalus



The neuromorphic bug eye cam: A 180-degree visual system for drones, 2013

<http://www.extremetech.com/extreme/156539-the-neuromorphic-bug-eye-cam-a-180-degree-camera-for-drones>

<https://omicspublishinggroup.wordpress.com/2013/04/24/neural-engineering/>

Virtualios smegenys - ateitis?



Smegenys kaip elektroninė mikroschema

69

Neuromarketingas



70