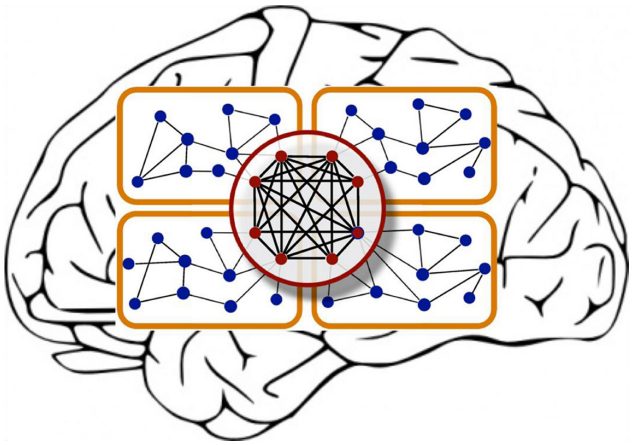
Neuroinformatika



1

Informatikos termino atsiradimas

Informatik:

Automatische Informationsverarbeitung

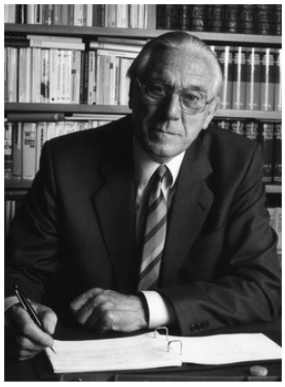
Karlas Šteinbuchas

• Vokiečių kibernetikas, 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

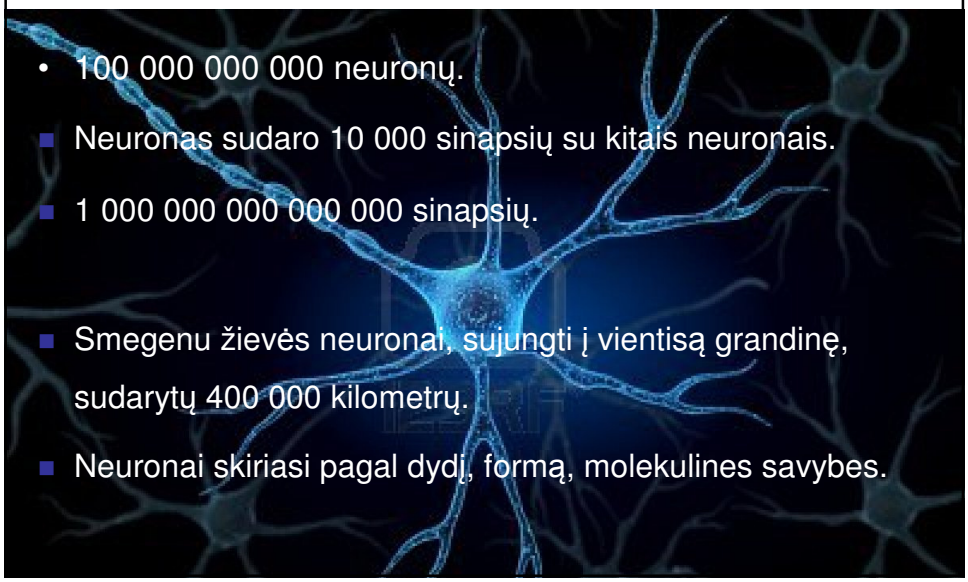
5

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....**

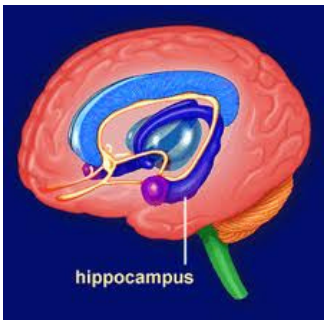
However, the neuroscience community is not yet fully engaged in exploiting the rich array of data currently available, nor is it adequately poised to capitalize on the forthcoming data explosion. "

Akil et al., Science, Feb 11, 2011

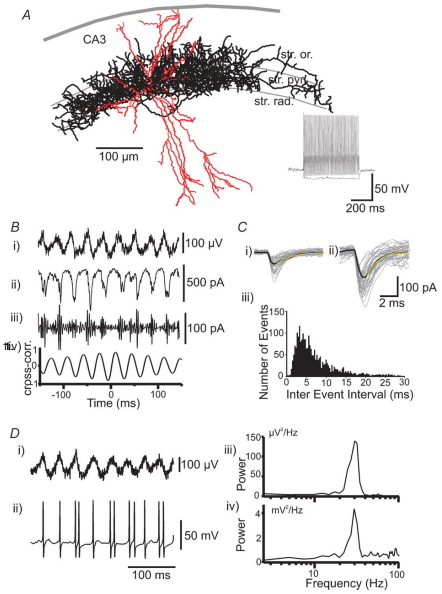
8

1.Duomenų bazės

Hipokampas



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

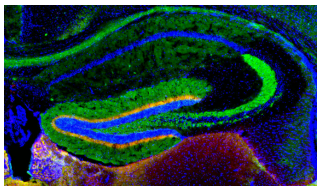


http://jp.physoc.org/content/562/1/131/F7.expansion

9

Duomenų bazės

Hipokampas

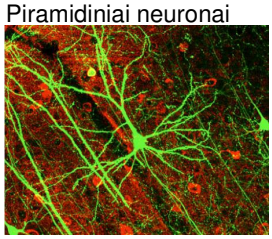


http://www.med.umich.edu/cdb/people/rgiger.html

Hipokampas

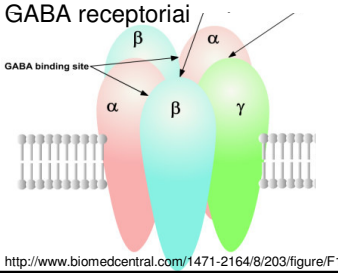
http://synapses.clm.utexas.edu/anatomy/hippo/hippo2.stm

Piramidiniai neuronai

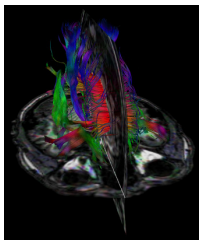


http://www.thecuriousneuron.com/

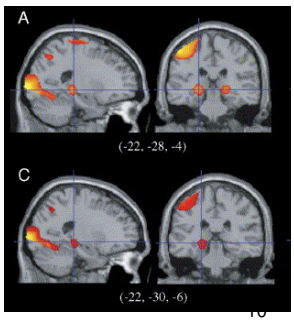
GABA receptoriai



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



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



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

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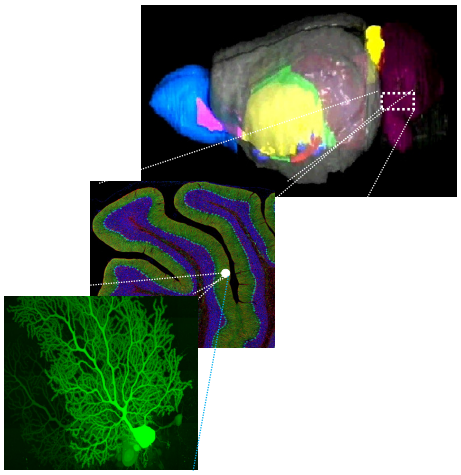
Duomenų sudėtingumas

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



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

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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)
    - Cheminiais reagentais apdorotų audinių vaizdai (erdvinė skalė nuo mikronų iki cm)
    - Optiniai įtampos ir cheminių reagentų įrašai
  - Centrinės ir periferinės nervų sistemos atlasai

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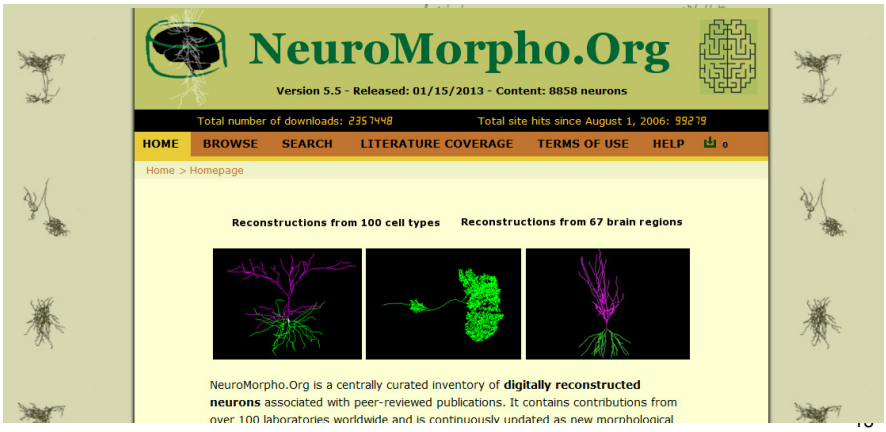
Duomenų bazė NeuroMorpho

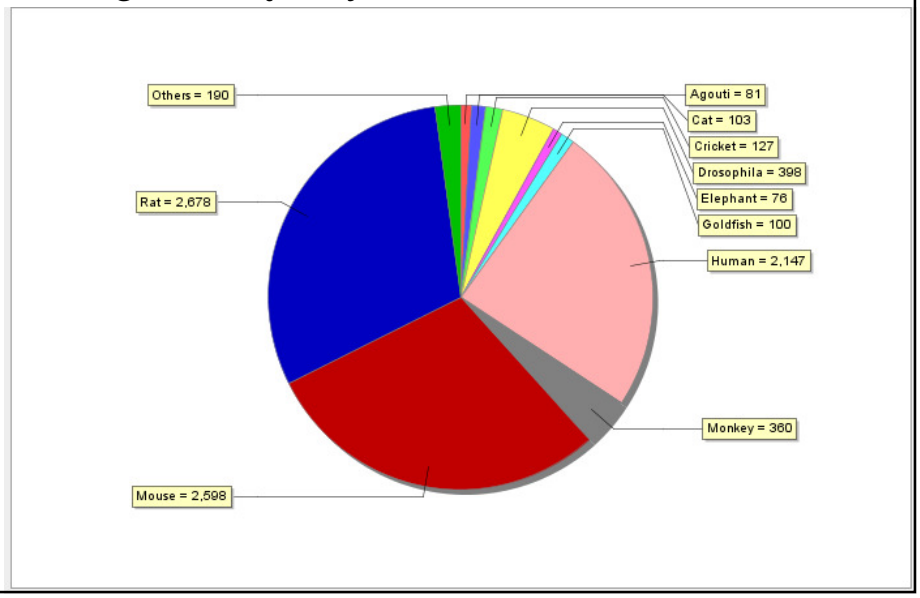
- Morfologinė neuronų rekonstrukcija
- Version 5.5 - Released: 01/15/2013 - Content: 8858 neurons, 67 brain regions, contributions from 108 laboratories



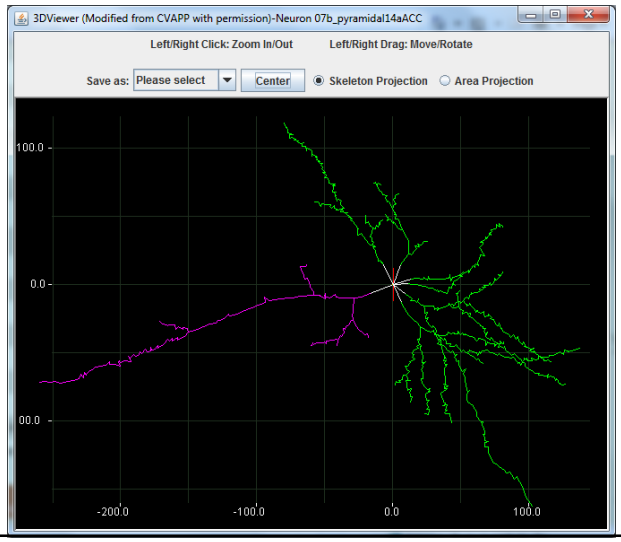
http://neuromorpho.org/neuroMorpho/index.jsp

Duomenų bazė NeuroMorpho

- Organizmų rūšys



Žmogaus piramidinis neuronas 07b_pyramidal14aACC



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Žmogaus piramidinis neuronas 07b_pyramidal14aACC

Details about selected neuron	
NeuroMorpho.Org ID :	NMO_01066
Neuron Name :	07b_pyramidal14aACC
Archive Name :	Allman
Species Name :	Human
Strain :	Not reported
Min Age :	23.0 years
Max Age :	23.0 years
Gender :	Male
Min Weight :	Not reported
Max Weight :	Not reported
Development :	Adult
Primary Brain Region :	Neocortex
Secondary Brain Region :	Anterior cingulate
Tertiary Brain Region :	Layer 5
Primary Cell Class :	Principal cell
Secondary Cell Class :	Pyramidal cell
Tertiary Cell Class :	Not reported
Original Format :	Neurolucida.asc
Experiment Protocol :	In vitro

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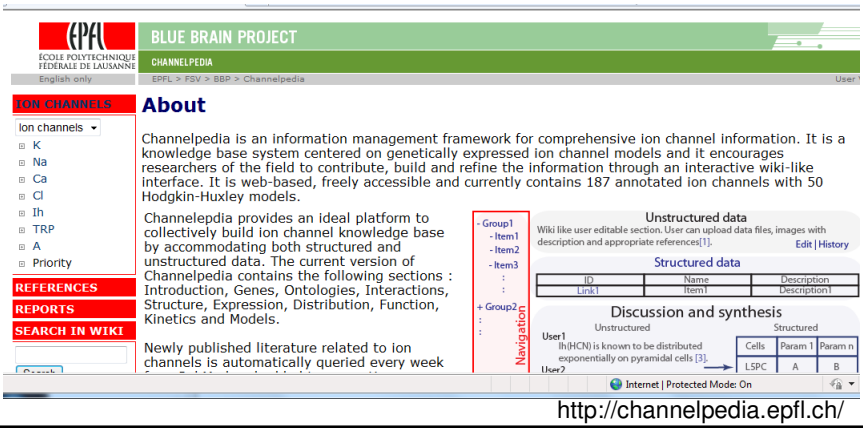
Duomenų bazė Channelpedia

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



http://channelpedia.epfl.ch/

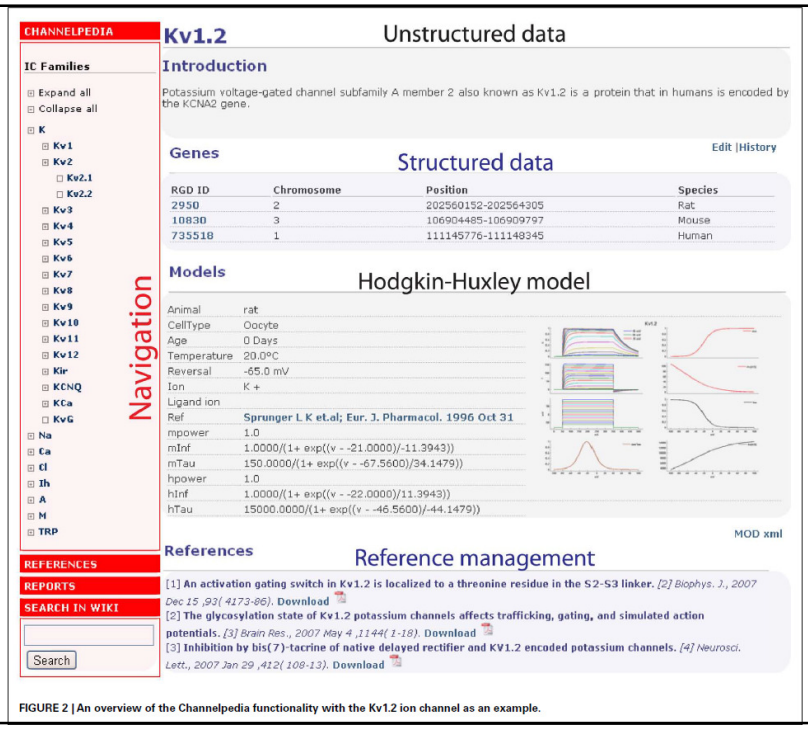


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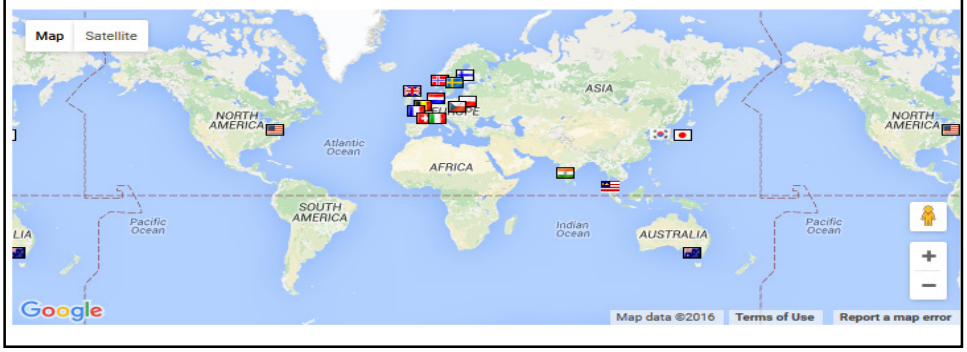
FIGURE 2 | An overview of the Channelpedia functionality with the Kv1.2 ion channel as an example.

INCF
International Neuroinformatics Coordination

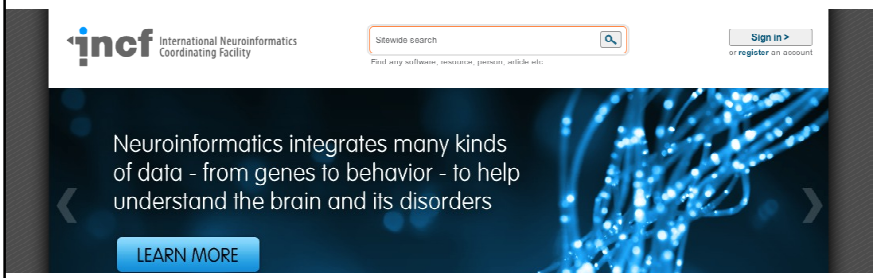
INCF National Nodes

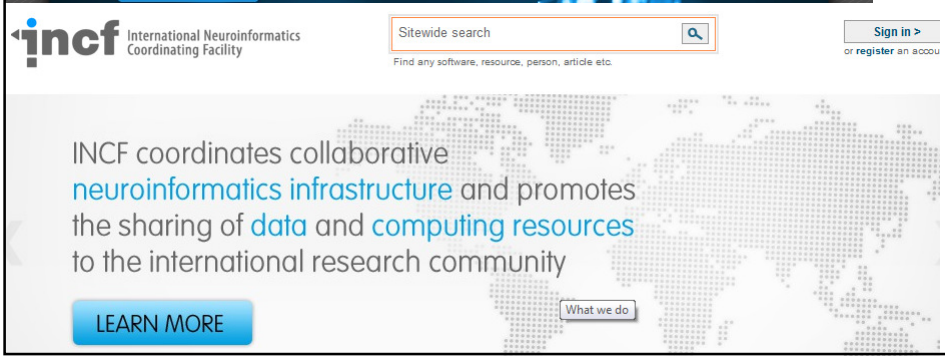
Each member country establishes a National Node to further the development of neuroinformatics and to interface with the INCF.



INCF tinklapis

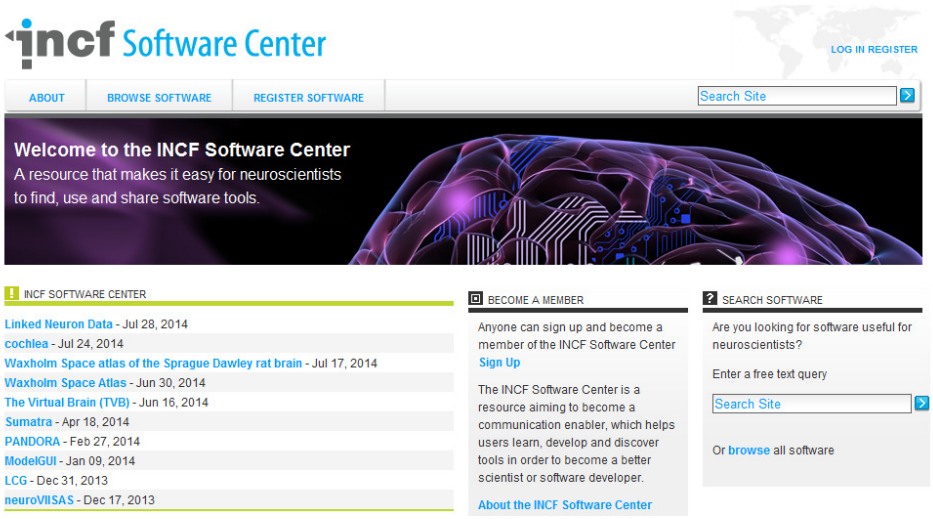
www.incf.org





INCF Software Center

- INCF Software Center – programinė įranga, skirta neuromokslams

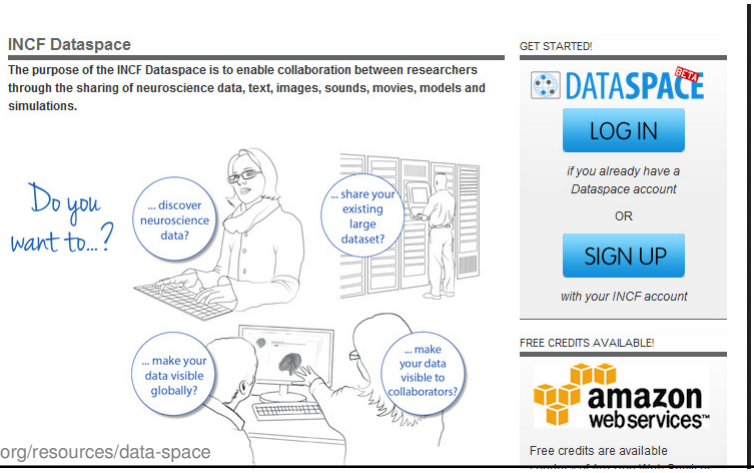


http://software.incf.org/

INCF Software Center
The Virtual Brain

INCF Data Space

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



http://incf.org/resources/data-space

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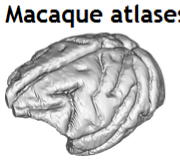
INCF Programa Digital Brain Atlasing

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 Kötter and Wanke (2005)
- Paxinos Rhesus Monkey (2000)
- Markov, Misery et al. (2011)

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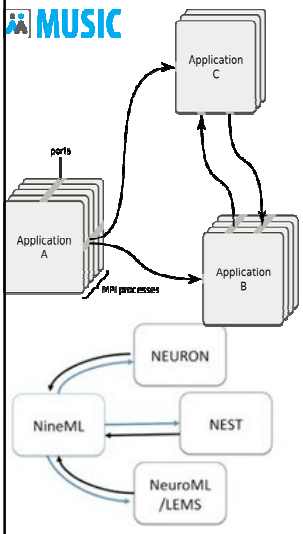
http://scalablebrainatlas.incf.org/main/index.php

INCF Programa MUSICS, NineML



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

Produktai ir paslaugos:
MUlti-SImulation Coordinator (MUSIC)
Network Interchange for Neuroscience Markup Language (NineML)

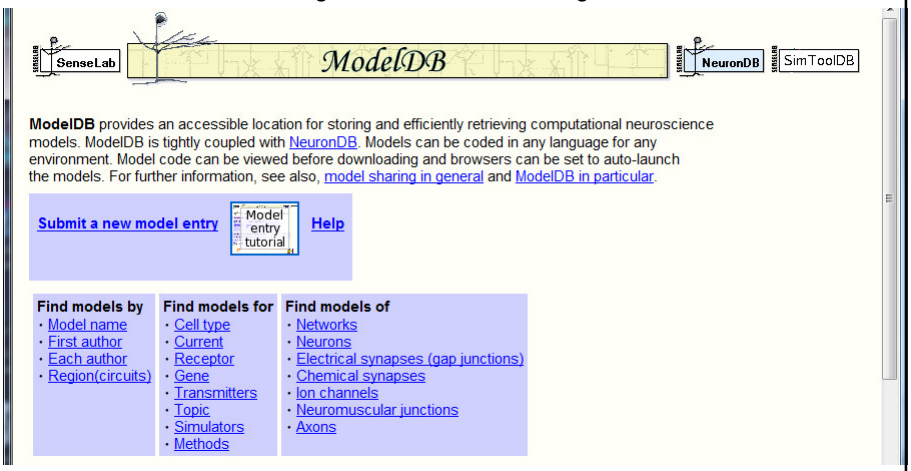
MUSIC: programinė įranga, leidžianti programiniams paketams keistis informacija simuliacijų/eksperimentų metu.

NineML: formali modelių aprašymo kalba, nepriklausanti nuo programinio paketo

25

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

NEURON ModelDB Modelių duomenų bazė



- https://senselab.med.yale.edu/modeldb/

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2. Specializuota programinė įranga

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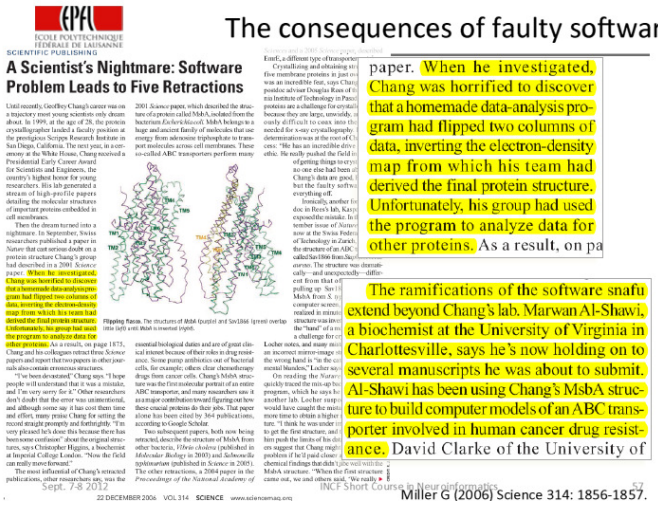
Programinės įrangos svarba



The consequences of faulty software

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. In 1999, at the age of 28, the protein crystallographer landed a faculty position at the prestigious Scripps Research Institute in San Diego, California. The next year, in a ceremony at the White House, Chang received a Presidential Early Career Award for Scientists and Engineers, the country's highest honor for young researchers. His lab generated a stream of high-profile papers detailing the molecular structures of important proteins embedded in cell membranes.

Then the dream turned into a nightmare. In September, Swiss researchers published a paper in *Nature* that cast serious doubt on a protein structure Chang's group had described in a 2001 *Science* paper. When he investigated, Chang was horrified to discover that a homemade data-analysis program had flipped two columns of data, inverting the electron-density map from which his team had derived the final protein structure. Unfortunately, his group had used the program to analyze data for other proteins. As a result, on page 1875, Chang and his colleagues retract three *Science* papers and report that two papers in other journals also contain erroneous structures.

"I've been devastated," Chang says. "I hope people will understand that it was a mistake, and I'm very sorry for it." Other researchers don't doubt that the error was unintentional, and although some say it has cost them time and effort, many praise Chang for setting the record straight promptly and forthrightly. "I'm very pleased he's done this because there has been some confusion" about the original structures, says Christopher Higgins, a biochemist at Imperial College London. "Now the field can really move forward."

The most influential of Chang's retracted publications, other researchers say, was the 2001 *Science* paper, which described the structure of a protein called MsbA, isolated from the bacterium *Escherichia coli*. MsbA belongs to a huge and ancient family of molecules that use energy from adenosine triphosphate to transport molecules across cell membranes. These so-called ABC transporters perform many essential biological duties and are of great clinical interest because of their roles in drug resistance. Some pump antibiotics out of bacterial cells, for example; others clear chemotherapy drugs from cancer cells. Chang's MsbA structure was the first molecular portrait of an entire ABC transporter, and many researchers saw it as a major contribution toward figuring out how these crucial proteins do their jobs. That paper alone has been cited by 364 publications, according to Google Scholar.

Two subsequent papers, both now being retracted, describe the structure of MsbA from other bacteria, *Vibrio cholera* (published in *Molecular Biology* in 2003) and *Salmonella typhimurium* (published in *Science* in 2005). The other retractions, a 2004 paper in the *Proceedings of the National Academy of*

Flipping flaps. The structures of MsbA (purple) and Sav1866 (green) overlap little (left) with MsbA in inverted (right).

22 DECEMBER 2006 VOL 314 SCIENCE www.sciencemag.org

paper. When he investigated, Chang was horrified to discover that a homemade data-analysis program had flipped two columns of data, inverting the electron-density map from which his team had derived the final protein structure. Unfortunately, his group had used the program to analyze data for other proteins. As a result, on pa

The ramifications of the software snafu extend beyond Chang's lab. Marwan Al-Shawi, a biochemist at the University of Virginia in Charlottesville, says he's now holding on to several manuscripts he was about to submit. Al-Shawi has been using Chang's MsbA structure to build computer models of an ABC transporter involved in human cancer drug resistance. David Clarke of the University of

Miller G (2006) Science 314: 1856-1857.

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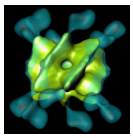
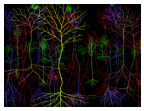
Programinė įranga

- 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





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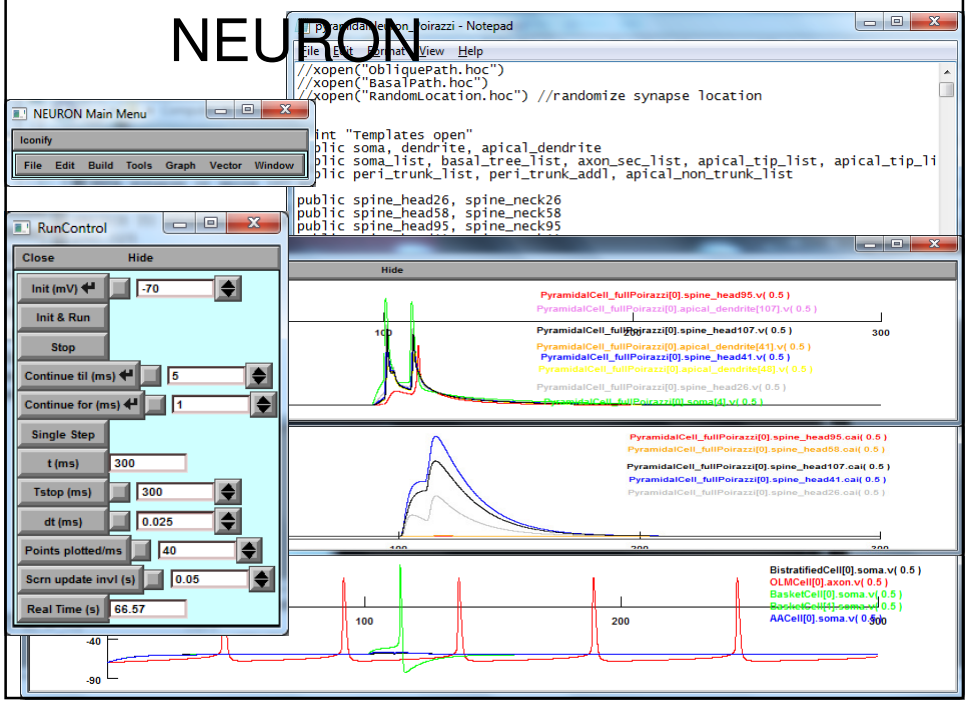
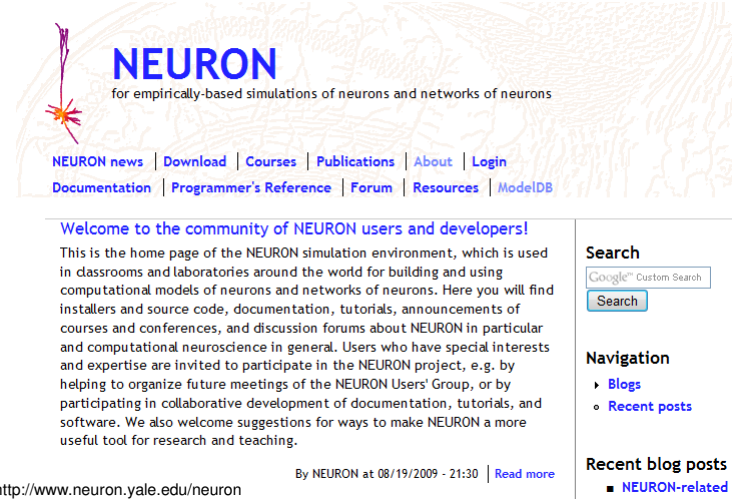
NEURON



NEURON

Programinis paketas, skirtas biologinių neuronų ir jų tinklų modeliavimui



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

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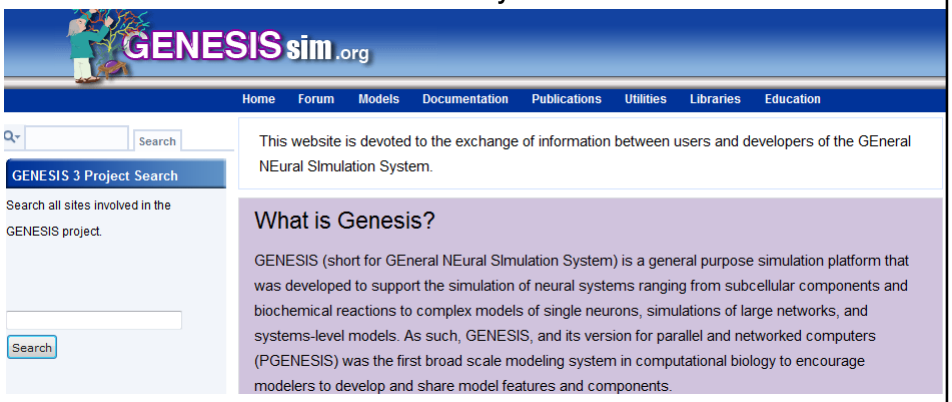
GENESIS

- GEneral NEural SImulation System



http://genesis-sim.org/

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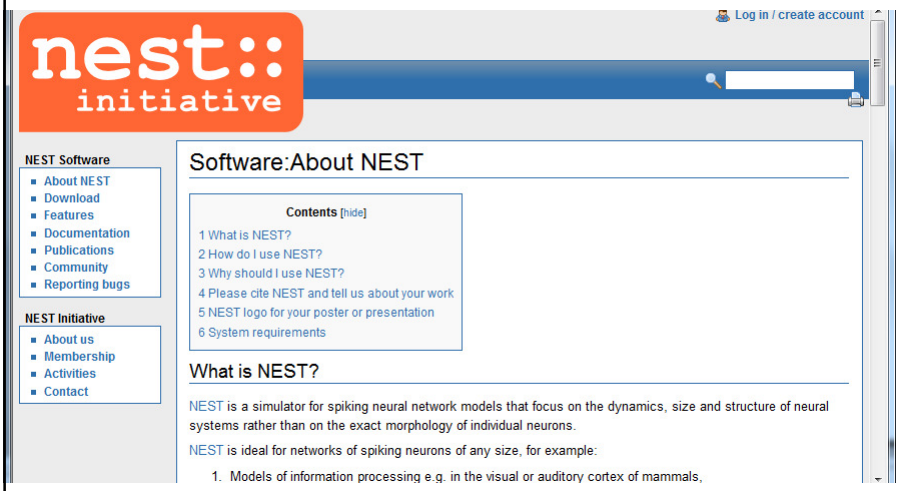
NEST

Programinis paketas, skirtas dideliems neuronų tinklams modeliuoti



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

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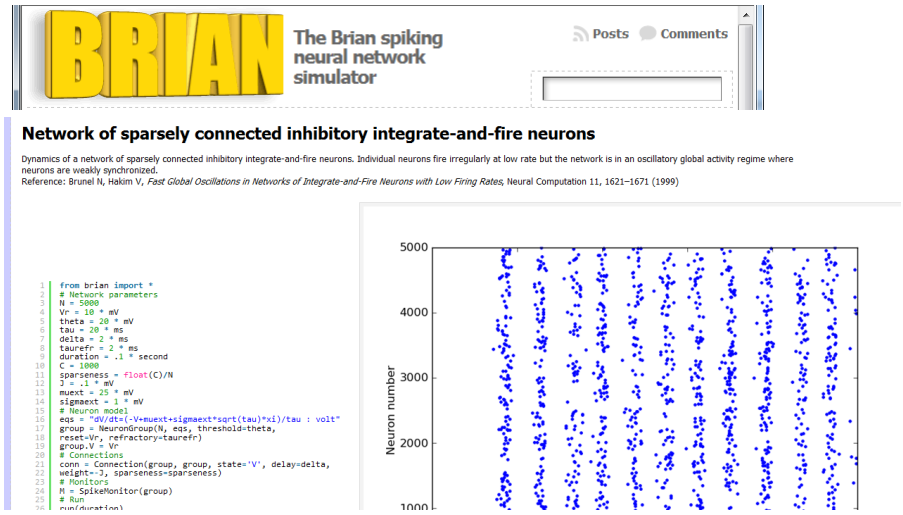
BRIAN

Programinis paketas, skirtas dideliems neuronų tinklams modeliuoti



http://briansimulator.org

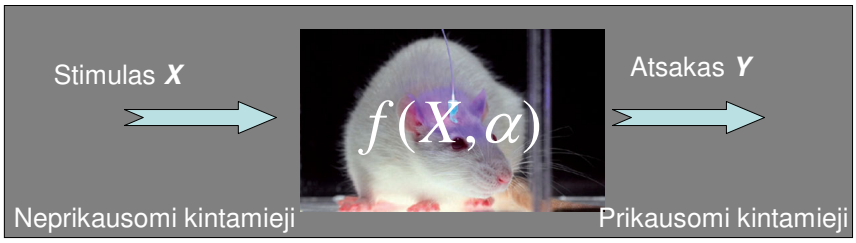
3. Nervų sistemos modeliai

- Kas yra modelis?

http://www.mmabarrgout.com/modules/com_updateman/motor-neuron-model-855.html

35

Matematinio modelio apibrėžimas



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

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Nervų sistemos modeliai

- Matematinis neurono modelis

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

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

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Modeliavimo žingsniai

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

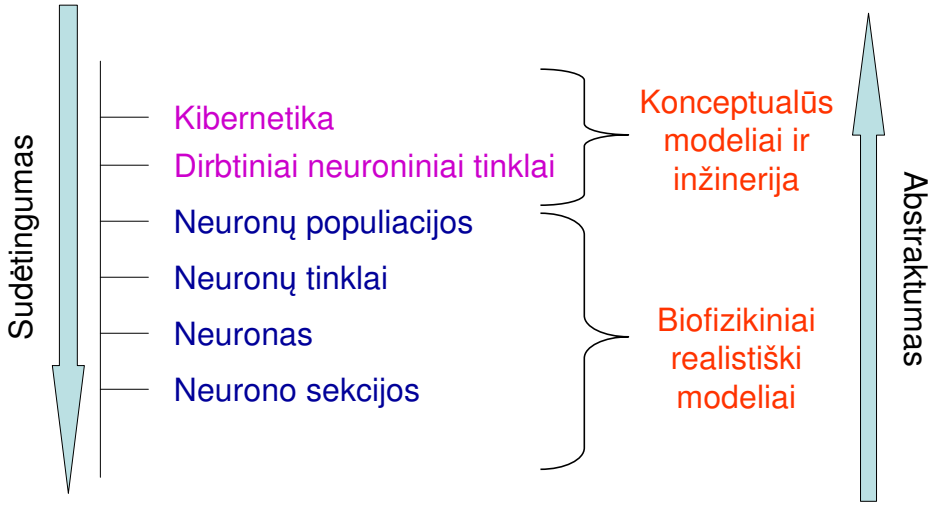
39

Nervų sistema: sandaros lygmenys

CNS	1m	(elgesys)
Grandinės tarp sričių	10cm	(tinklainė, hipokampas)
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



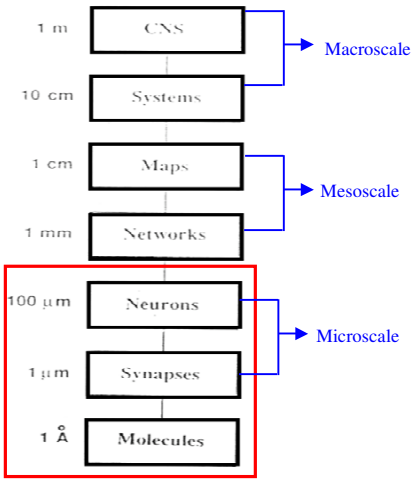
Biofizikinius modelius sunku susieti su elgesiu

41

Computational Neuroscience

Neuronų mikrograndinių modeliai

Vieno neurono ir molekulinių sąveikų neurone modeliai



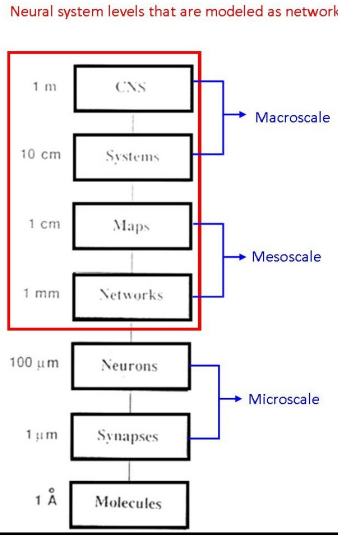
- Atmintis
- Mokymasis
- Vystymasis
- Sensorinės informacijos apdorojimas
- Neurologinės ir psichikos ligos

- Makroskalė: smegenų sritys, sujungtos aksonų pluoštais
- Mezoskalė: neuronų tinklai, jungiantys neuronų populiacijas (pvz., smegenų žievės mikrokolonėlės)
- Mikroskalė: sinapsės, mikrograndinėlės

42

Cognitive Neuroscience

Kognityvinių funkcijų neuroniniai modeliai



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

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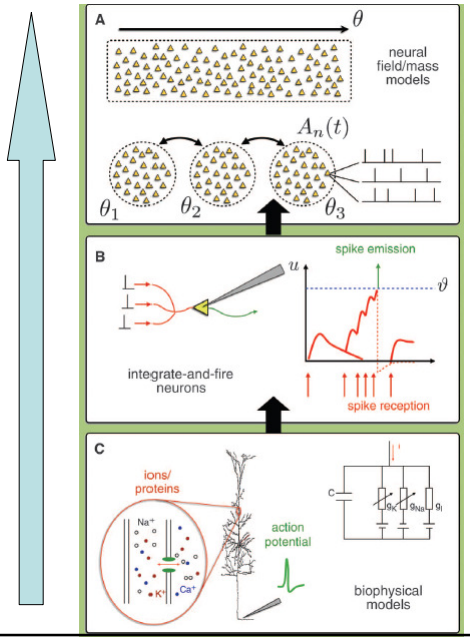
Bottom-up modeliavimo principas



Neuronų populiacija

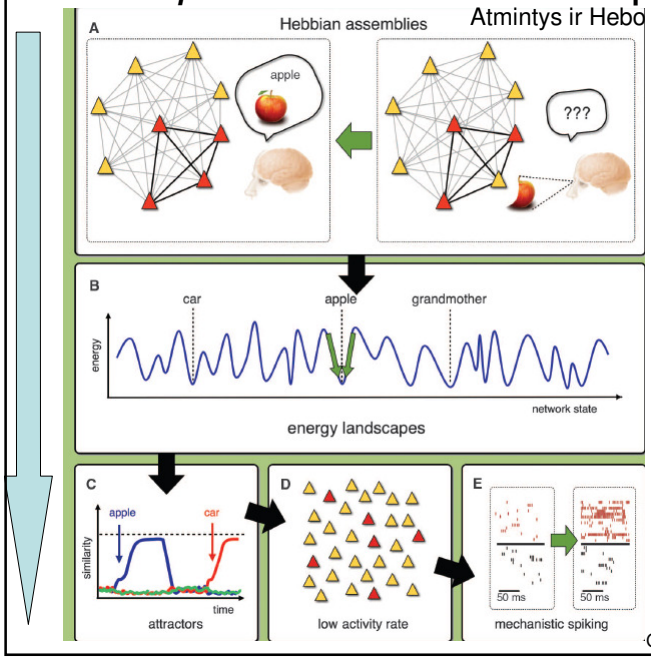
Supaprastintas neurono modelis (*Integrated-and-fire*)

Biofizikinis neurono modelis

44

Gerstner ir kiti, 2012

Top-down modeliavimo principas



Atmintys ir Hebo mokymo taisyklė

A: Neuronų subpopuliacijos aktyvumas koduoja tam tikrą reiškinį/objektą

Objektas/reikšknys atkuriamas iš dalinės informacijos

B: Aktyvumas – energijos funkcija

C: Panašumo funkcija

D: Neuronų aktyvumas

E: Veikimo potencialus generuojančių neuronų aktyvumas

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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)

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Du modeliavimo metodai

1. Analitinis
   - tikslūs matematiniai skaičiavimai

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

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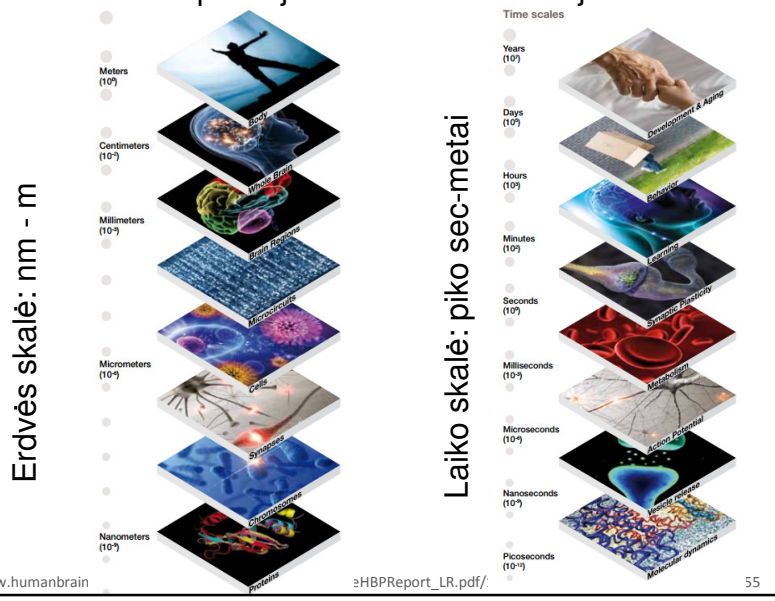
Daugiaskalinis modeliavimas (*Multiscale modeling)*

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



https://www.humanbrain ɛHBPReport_LR.pdf/ 55

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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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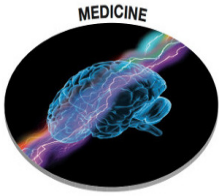
The Human Brain project 2013-2023 Tyrimų kryptys

- 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

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/

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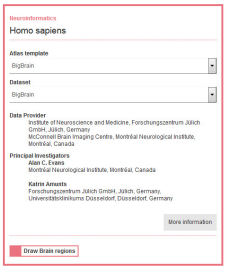
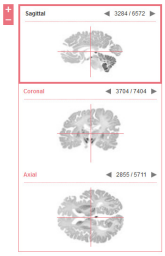
Homo sapiens Brain Atlas

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





20000 micron

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

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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

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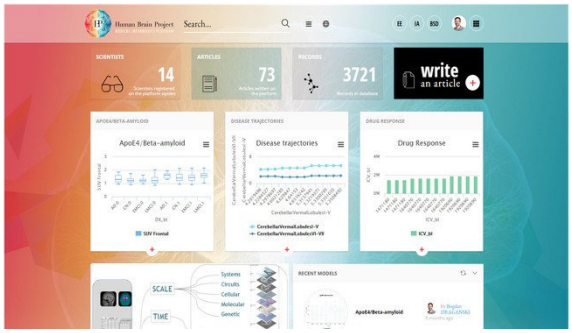
Medical Informatics Platform

- 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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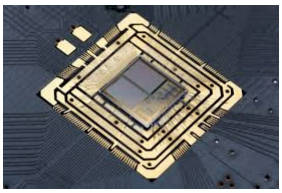
Neuromorphic Computing Platform

- 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 x 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

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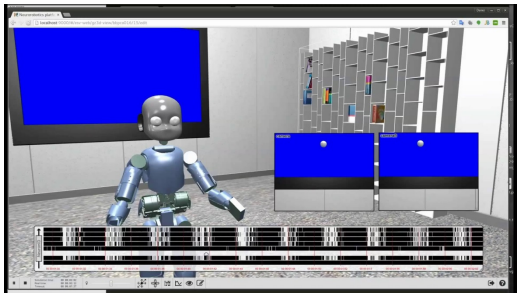
Neurorobotics Platform

- 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



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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

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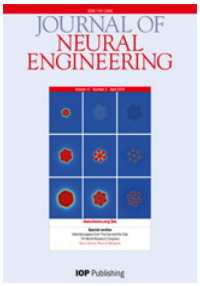
4. Neuroinžinerija ir neuromorfinės sistemos

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

http://iopscience.iop.org/1741-2552/ https://www.youtube.com/watch?v=jeLghZ8GASA

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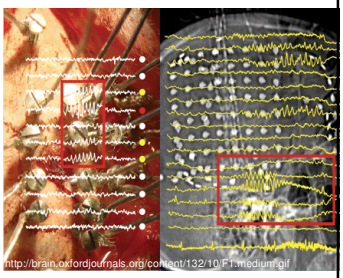
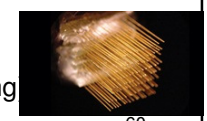
Smegenų-kompiuterio sąsaja

Brain-Machine Interface (BMI)

- Smegenų-kompiuterio sąsaja - sistema, kuri nuskaito ir analizuoja 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 rezonanas (MRI, fMRI)
- Invaziniai metodai:
  - Elektrokortikografija (Electrocorticography,ECoG)
  - Smegenų masyvai (Brain arrays)
  - Neuronų aktyvumo nuskaitymas (Single unit recording



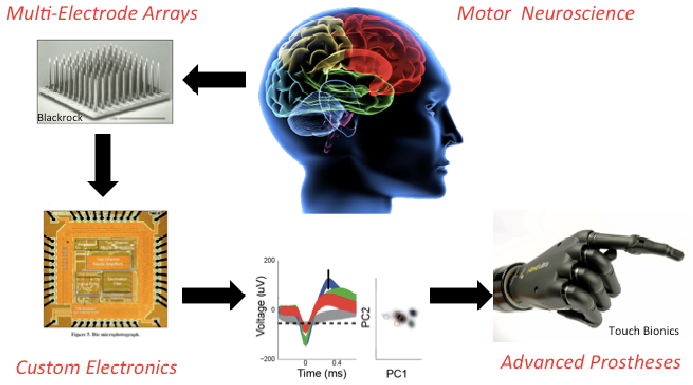


60

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

Smegenų – kompiuterio sąsaja neuroprotezams valdyti

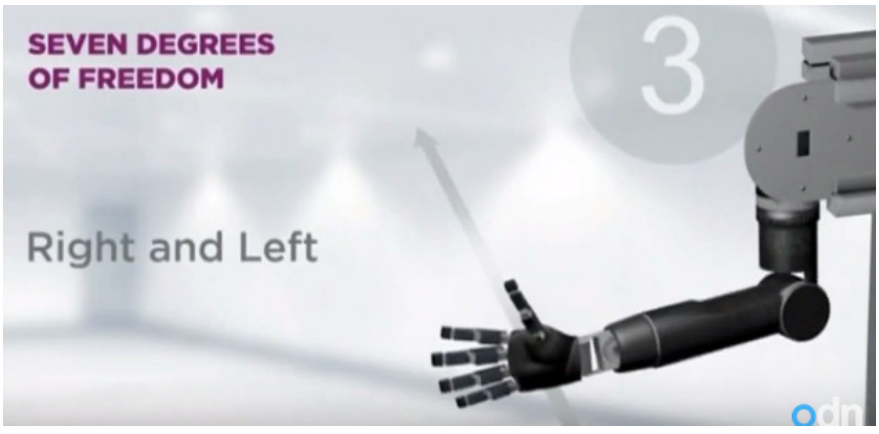
Neuroprotezai – dirbtiniai prietaisai, valdomi smegenų ar periferinių nervų signalais ir pakeičiantys nefunkcionuojančias biologinės sistemos dalis.



Mitčigano universitetas, JAV
http://chestekresearch.engin.umich.edu/

Mintimis valdoma ranka

- Žmogaus smegenų signalai perduodami dirbtinei rankai



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

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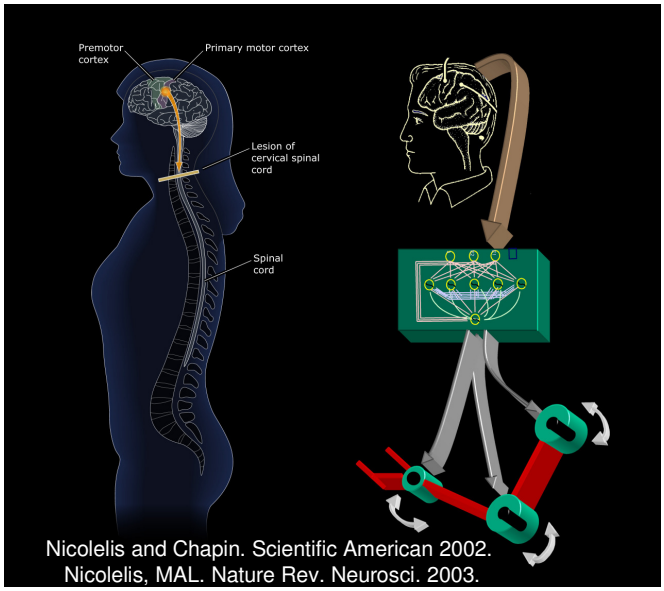
Cortical Neuroprosthesis for Restoring Motor Functions

Miguel A. L. Nicolelis
Depts. Neurobiology and Biomedical Engineering,
Center for Neuroengineering, Duke University



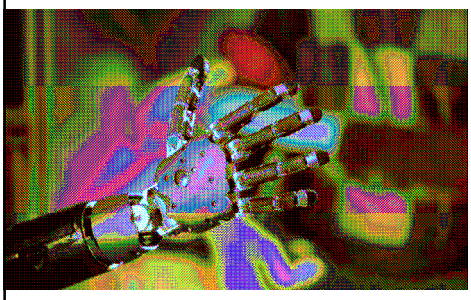
Nicolelis and Chapin. Scientific American 2002.
Nicolelis, MAL. Nature Rev. Neurosci. 2003.

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



Scientific American, September 2012

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

Paraplegic in robotic suit kicks off World Cup

By Alejandra Martins and Paul Rincon
BBC news staff

www.sciencemag.org SCIENCE VOL 338 21 DECEMBER 2012

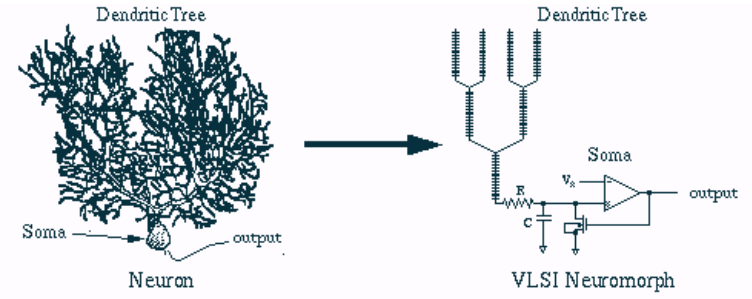
Patil et. al. Neurosurgery, 2004

Neuromorfinės sistemos

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

Funkcionavimo principai yra pagrįsti dėsniais, stebimais biologinėse neuro sistemose.

Pasižymi didele veikimo sparta ir mažu sunaudojamos energijos kiekiu.



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

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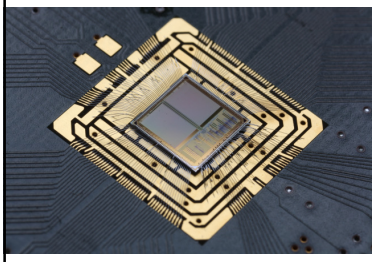
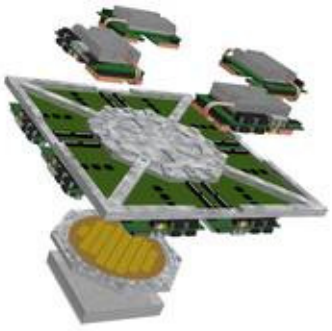
Spikey neuromorfinė sistema
The Human Brain Project





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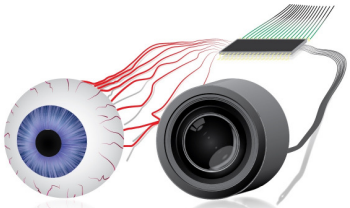
Heidelbergo universitetas, Vokietija

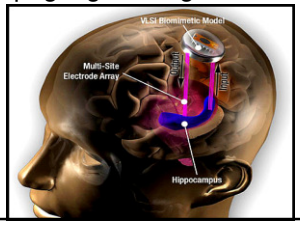
Neuromorfinės sistemos

- **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 vietos nustatymas pagal garso 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-visual-system-for-drones

John Hewitt

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

Virtualios smegenys - ateitis?

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Smegenys kaip elektroninė mikroschema

Neuromarketingas

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