Seminar on Computational Neuroscience

Organization and Introduction

Ilya Kuzovkin

COMPUTATIONAL NEUROSCIENCE
Research group at the University of Tartu

TARTU ÜLIKOOL · UNIVERSITAS TARTUENSIS · 1632

IT Akadeemia
toetab Skype™

Course logistics

Time & Place: Fridays @ 10:15 in room 206

Contacts:

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Course page: https://courses.cs.ut.ee/2014/neuroseminar

To do:

Ask questions
Attend 75% of seminars (12)
Read and present a paper
Write short summary about your paper

Choose your article

- Pick an article from the list on the course web page or propose your own
- Tell me the date when you would like to present it (see Timetable on the course page)
- Present it! :)

Ask and Discuss everything

David Marr, 1982

A computational investigation into the human representation and processing of visual information

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Matteo Carandini, 2012

From circuits to behavior: a bridge too far?

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From circuits to behavior: a bridge too far?

Leslie G Valiant, 2014

What must a global theory of cortex explain?

David Marr: History

- Works by **Barlow**, Hill, Levick, Lettwin in years 1950-70 showed that it is possible **map** regions of a brain to their **function** by **stimulating** and **observing** the **response.**

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- Neurophysiology and psychophysics were able to **map** functional roles to cells and **describe** the behaviour, but those studies were not able to **explain** the process.

- It became **clear** that with such level of understanding one **cannot** simulate same behaviour in **artificial** system.

David Marr: Three Layers

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- **Each** one must be understood to get the final picture
- **Loosely** related, **one or two** are enough to **explain** some phenomena
- Each problem should be **addressed** on appropriate level

David Marr: Consequences

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Necker cube illusion — which layer?

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Necker cube illusion — which layer?

Obvious?

Matteo Carandini: 30 years later

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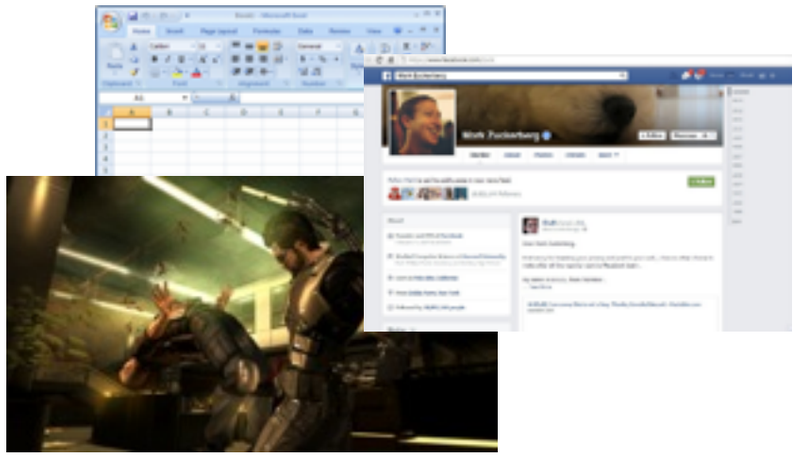

Psychologists

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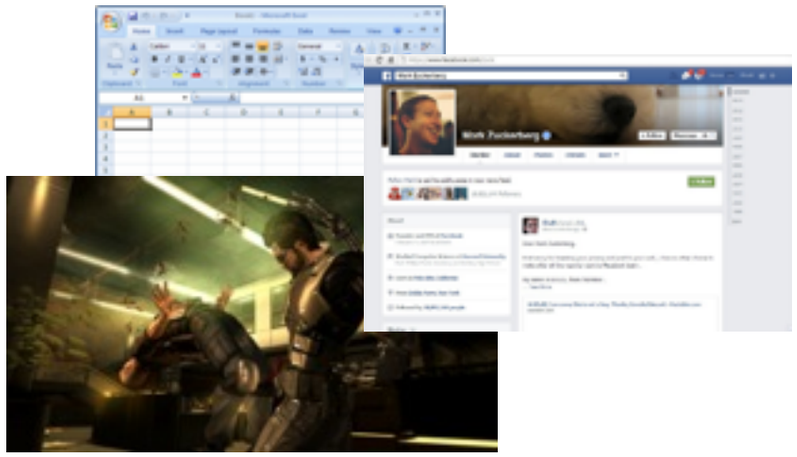

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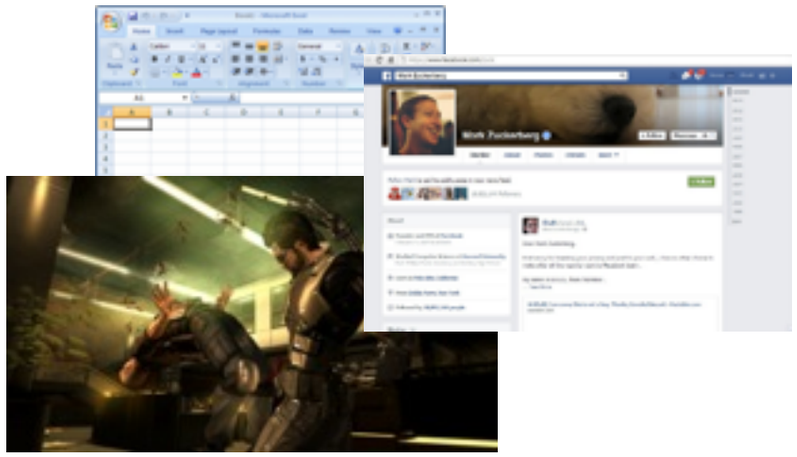

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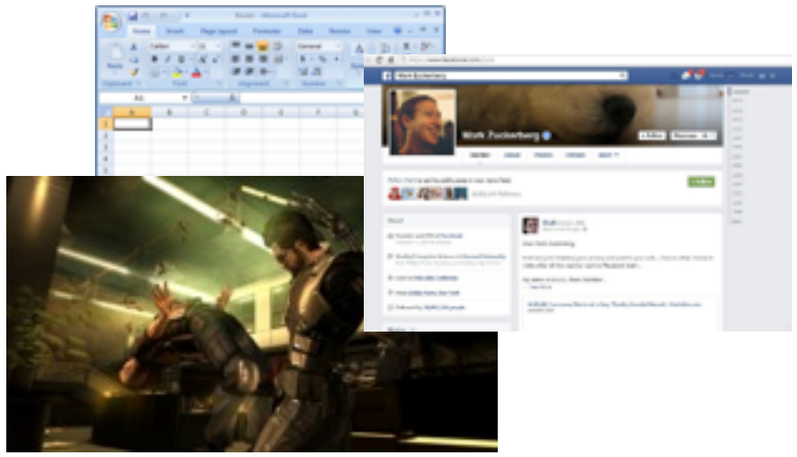

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… who?

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Matteo Carandini: Candidates for layer 2

Linear filtering

Convert input signal to linear output signals, each component of produced system has linear response

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Associative learning rules
Observe which combinations of inputs lead to which outputs, and estimate which patterns occur most reliably

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Cognitive spatial maps

A way to associate pieces of data with symbols, helps to reduce cognitive load. Symbols can be meaningfully organized into maps.

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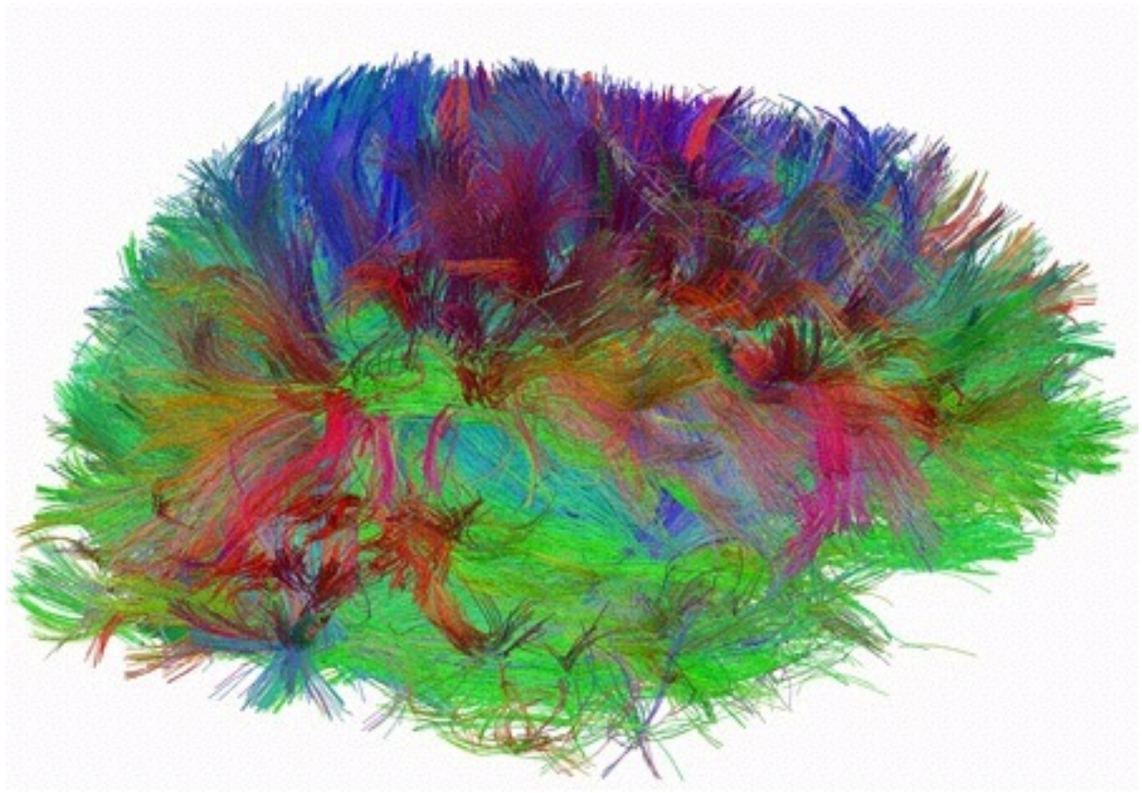
Constrained trajectories in dynamical systems

Analysis of the trajectories of the propagation of the input signal gives an insight on the functional role of the system

Matteo Carandini: Alternatives to Marr



Connectome?

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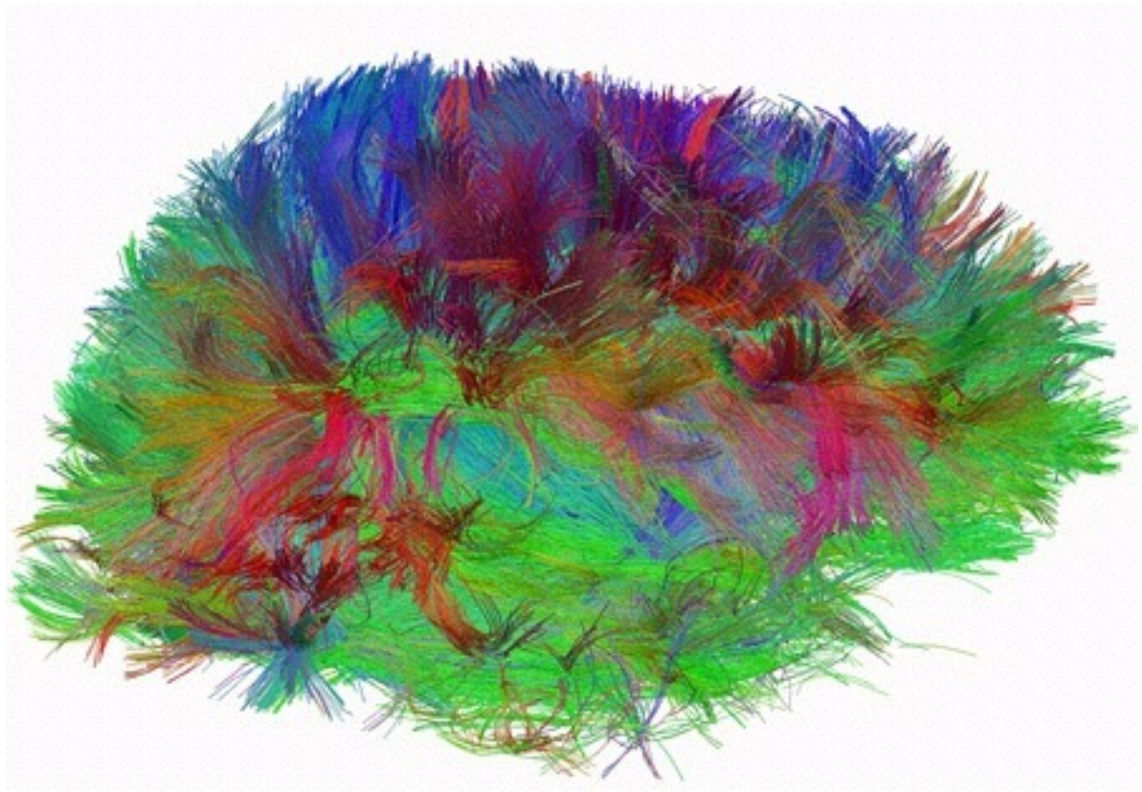

Connectome?

Full network

+

fully detailed structure

Simulome?

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Marr's model is not good enough?

Leslie Valiant

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*"At present there is **no** generally accepted **theory** of how cognitive phenomena arise from **computations** in **cortex**."*

*"Further, there is **no consensus** on how the search for one should be **refocussed** so as to make it more **fruitful**."*

*"Astonishingly, the question of **proposing** general **theories** of **cortex** and subjecting them to experimental examination is currently **not** even a **mainstream** scientific activity."*

Leslie Valiant: Marr is not enough

Communication			
Need to send **n** bit to communicate **n**-bit message			

Leslie Valiant: Marr is not enough

Communication	Computation		
Need to send **n** bit to communicate **n**-bit message	Computational complexity		

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Communication	Computation	Learning	
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Communication	Computation	Learning	Evolution
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"*successful theory will have to show additionally, **how** the **quantitative challenges** that need to be faced **are solved** in cortex*"

Leslie Valiant: you should do it like that

- Compose a list of tasks that cortex uses to create cognition: Memorizing, Learning, Using the memory

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- Propose an experiment which could confirm or reject that cortex uses the algorithm

- Explain evolutionary path how brain has acquired those capabilities

Leslie Valiant: Desired properties

Good	Bad

… for **any** model of cortical computation

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Number of neurons, number of synapses, synaptic strength — all accounted quantitatively	Resources assumed unlimited (free)

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Leslie Valiant: Example

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Random access task			

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Leslie Valiant: Conclusion

Marr's layers are good, but it is **not enough**

The main **missing** ingredient is taking computational **complexity** into account

We need a **framework** in which computational **theories** of the cortex can be **created** and **tested**