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How to design brains on a chip

Luc Libralesso, Florian Larramendy, Vincent Jost, Frédéric Maffray, Thibault Honegger

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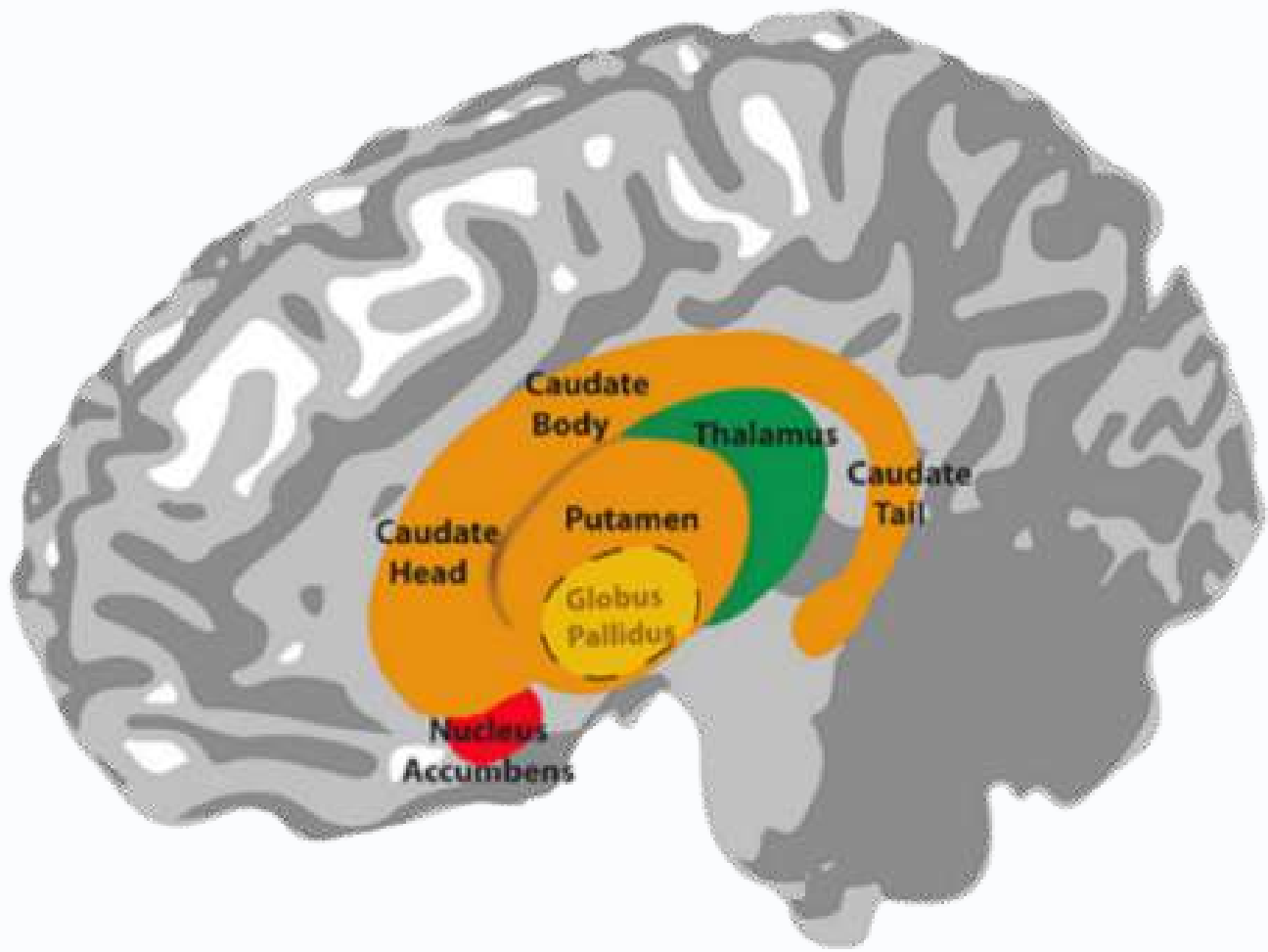
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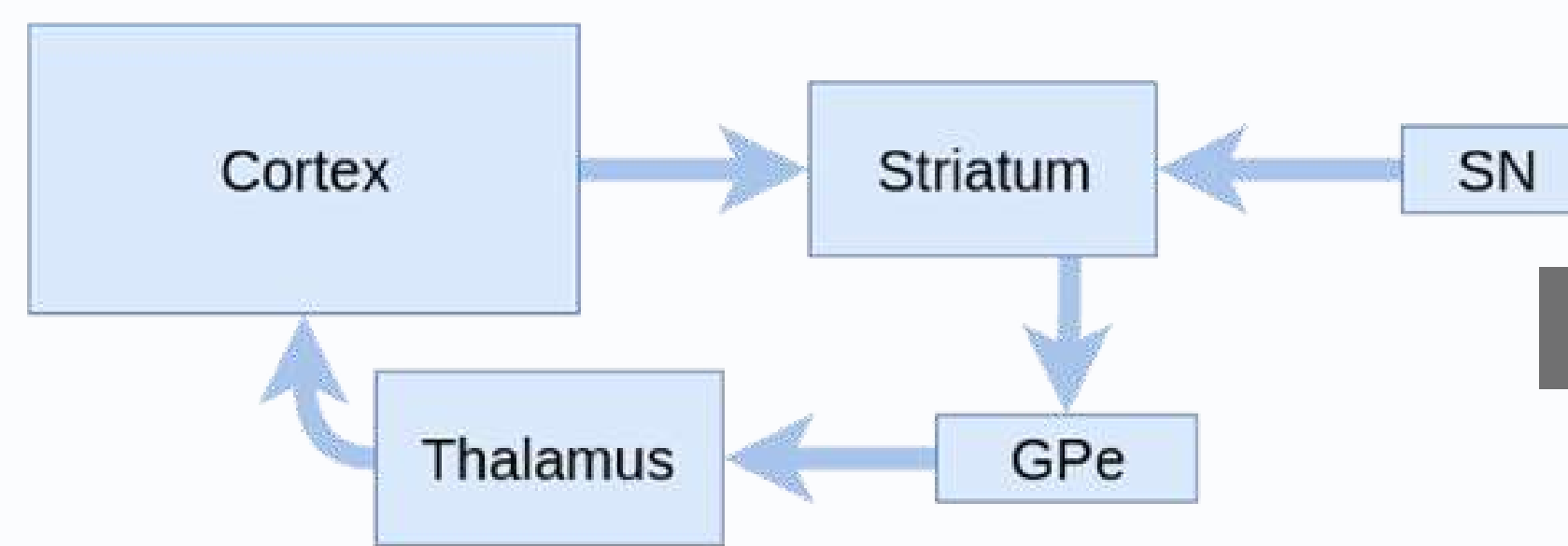
Typical workflow

I. NORMALIZED CHIP DESCRIPTION



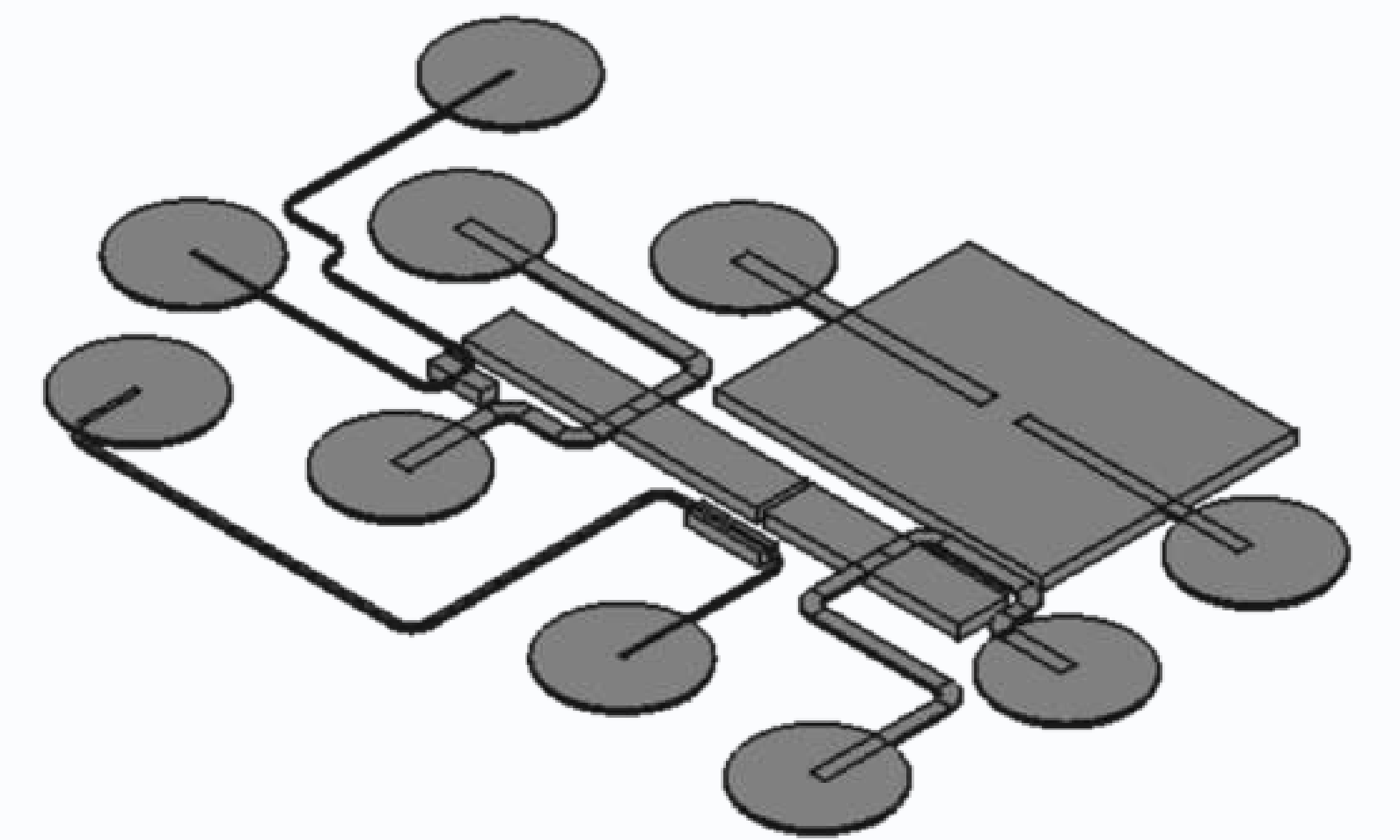
source: [1] One of several brain patterns we want to reproduce (basal ganglia loop)

II. TRANSITIONAL PROCESS



Extract graph structure. Each node has a number of neurons, each connection has a connectivity degree, and a maximal width

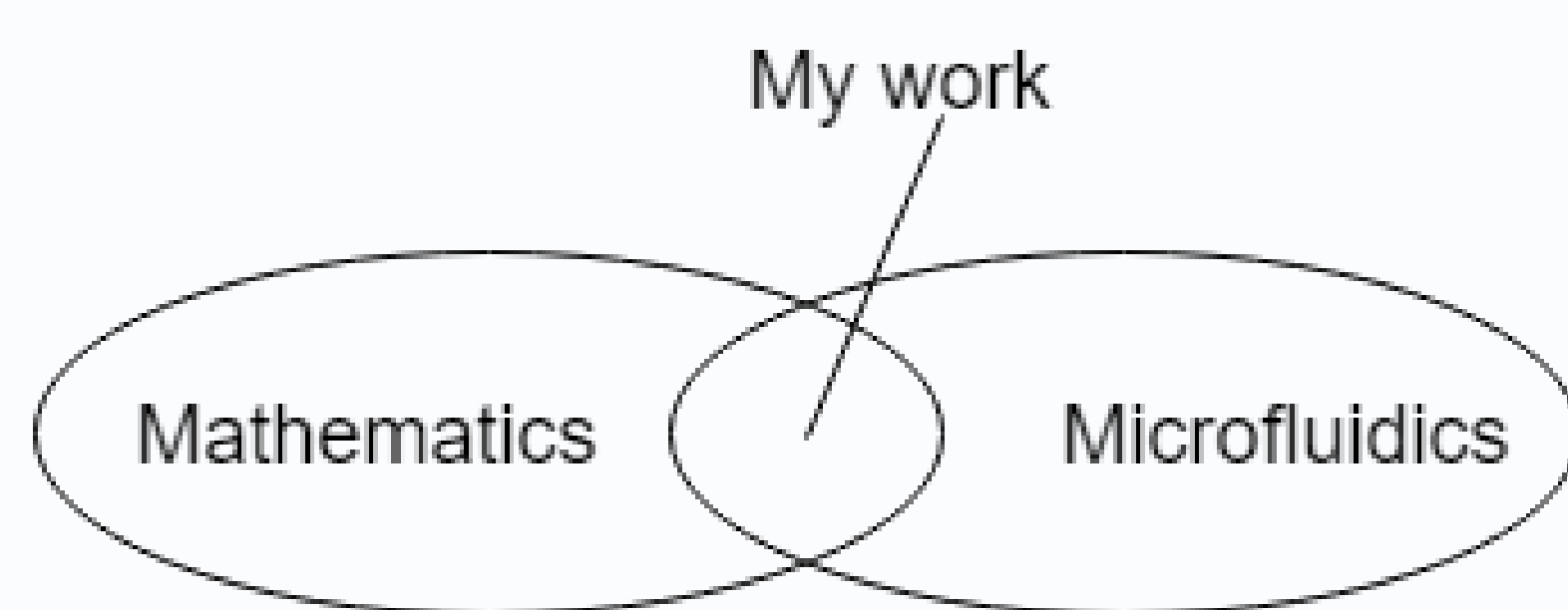
III. GENERATION OF CAO FILES



Final microfluidic chip, that represents the brain part

Goals

- Chip design is very complex, until now, designs were made by hand
- This work aims to use mathematical and computer tools to automate this process



Why a computer approach ?

Too much constraints and possibilities to be handled by a human

- Lots of choices to make:
 - Chamber positions
 - Lots of possible planar embeddings of a 3D structure
 - Channel dimensions (width, length, height)
 - Channel routing

• Microfluidic constraints:

- Navier-stokes equations.

$$\Delta z = \frac{\eta Q}{\rho g} \left(\frac{\lambda_{in} L_{in}}{W_{in} H_{in}^3} + \frac{\lambda_{ch} L_{ch}}{W_{ch} H_{ch}^3} + \frac{\lambda_{out} L_{out}}{W_{out} H_{out}^3} \right)$$

• Fabrication constraints:

- Two chambers should be not too close

• Neural-engineering constraints:

- Channel width and length related to their brain equivalent
- Each node contains a specific number of neurons

Work done so far

- Formal representation of chip requirements and chip designs
- Semi-automatic chip design from specifications
- Already done on several practical cases:
 - Basal ganglia loop (5 nodes)
 - Several toy models (2 to 4 nodes)

Perspectives

- Continue to implement brains models
- Study algorithms to optimize chamber placement
- Implement heuristics to route channels automatically

Bibliography

- [1] Sung-Joo Lim, Julie A Fiez, and Lori L Holt. How may the basal ganglia contribute to auditory categorization and speech perception? *Frontiers in neuroscience*, 8, 2014.

Chip Architecture

