Simplifying Neurorobotic Development with NCSTools

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Laurence Jayet Bray

Sergiu Dascalu

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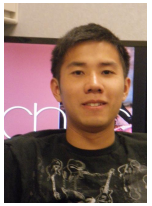

Undergraduate Students:

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Nitish Narala

Project Collaborators :

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Joshua Hegie

Facts:

- Founded in 2001
- Joint Research Center

Funding:

- ONR
- HRL Labs

Outline

- Introduction
  - Spiking Neural Models
  - Neurorobotics and VNR
  - NCS
- NCSTools
  - Motivation
  - Design
- Examples
  - Reward-Based Learning
  - Trust the Intent Recognition
- Questions?

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Introduction

- What is Computational Neuroscience?

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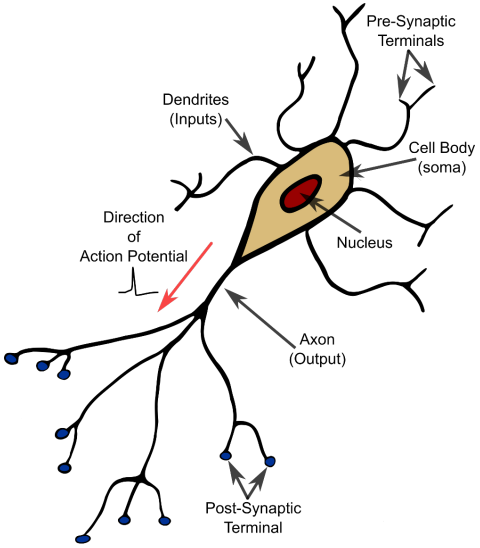
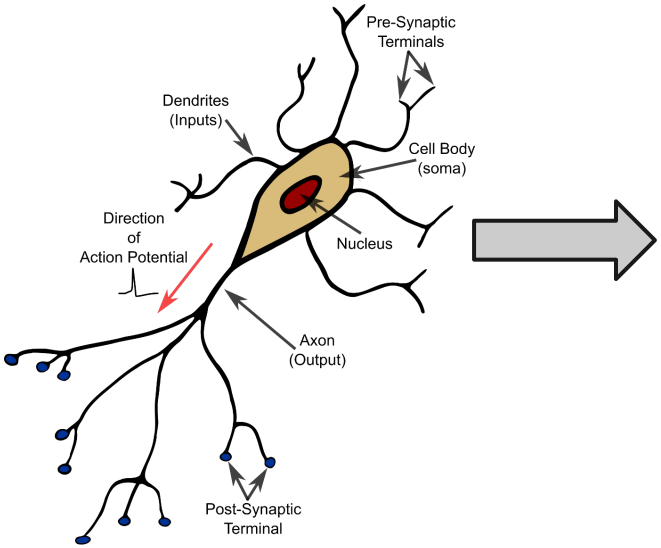


Introduction

- What is Computational Neuroscience?

$$I = C_M \frac{dV}{dT} + \bar{g}_K n^4 (V - V_K) + \bar{g}_{Na} m^3 h (V - V_{Na}) + \bar{g}_l (V - V_l)$$



$$\frac{dn}{dt} = \alpha_n (1 - n) - \beta_n n$$

$$\frac{dm}{dt} = \alpha_m (1 - m) - B_m m$$

$$\frac{dh}{dt} = \alpha_h (1 - h) - \beta_h h$$

$$\alpha_n = \frac{0.01(V + 10)}{e^{\frac{V - 10}{10}} - 1}$$

$$\beta_n = 0.125 e^{(V/80)}$$

$$\alpha_m = \frac{0.1(V + 25)}{e^{\frac{V + 25}{10}} - 1}$$

$$\beta_m = 4 e^{(V/18)}$$

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$$\beta_h = \frac{1}{e^{\frac{V + 30}{10}} + 1}$$

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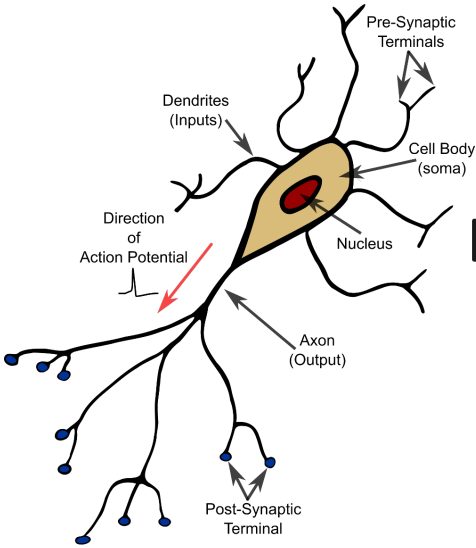

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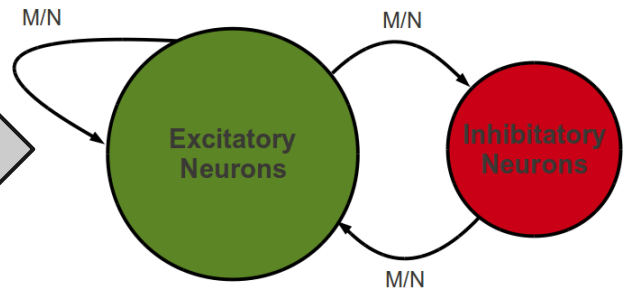

Introduction

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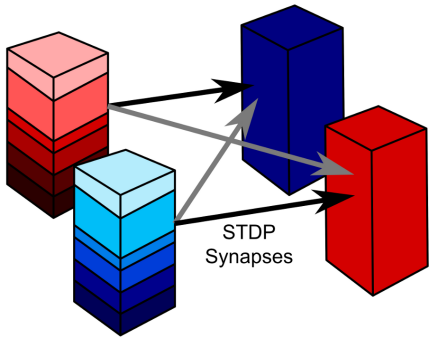

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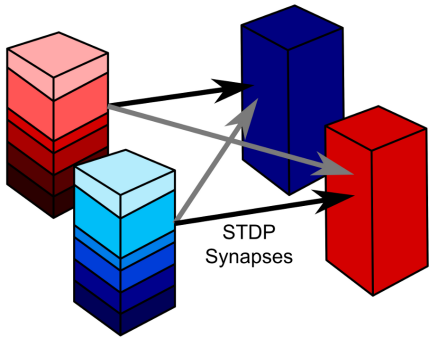
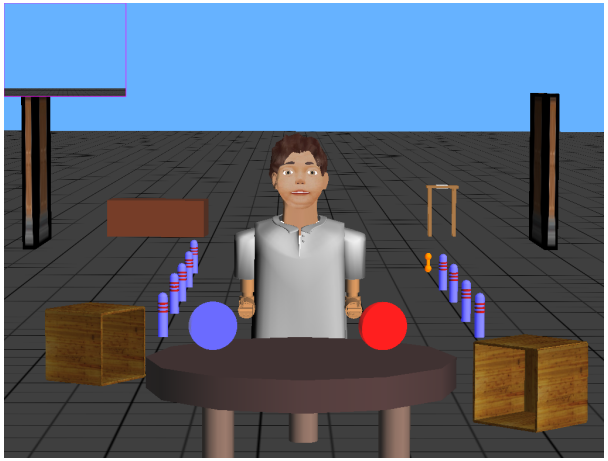
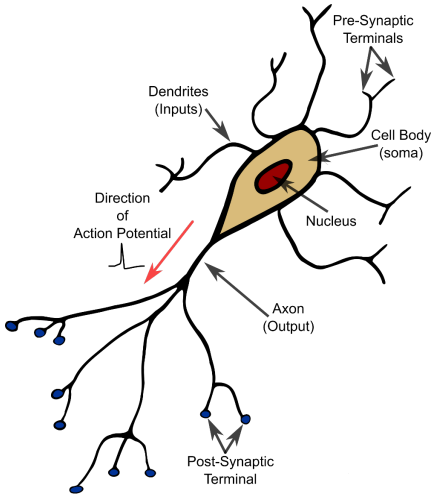




Introduction:
Spiking Neural Models

- Neurons are excitable cells that fire an action potential once a threshold voltage has been reached.



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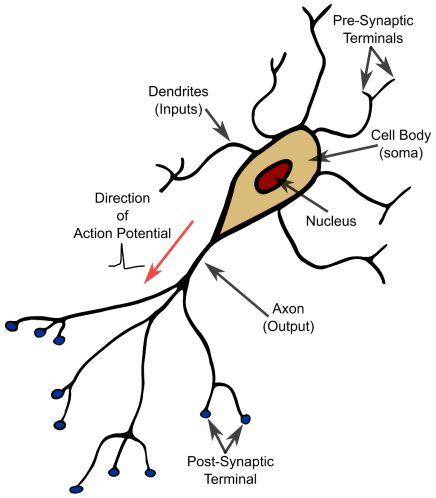
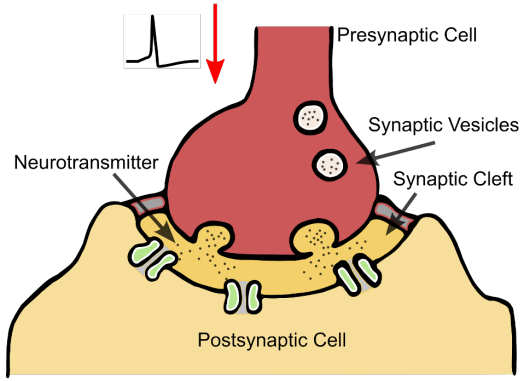
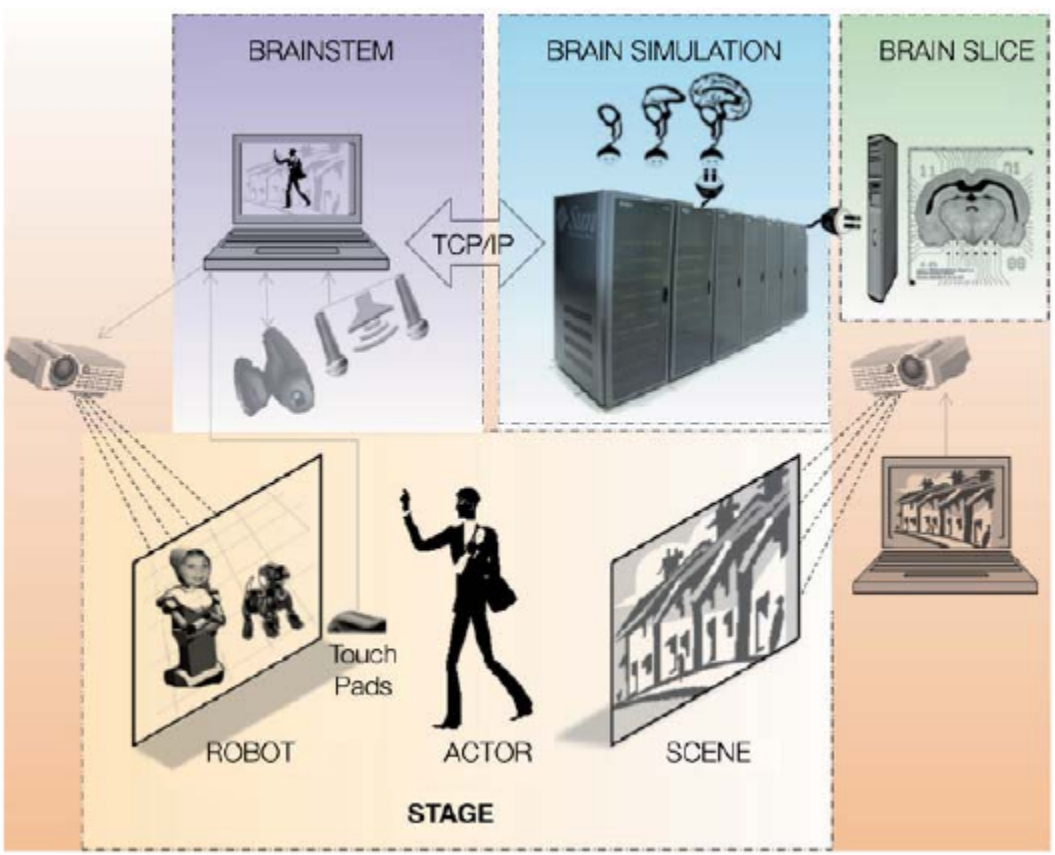
Spiking Neural Models

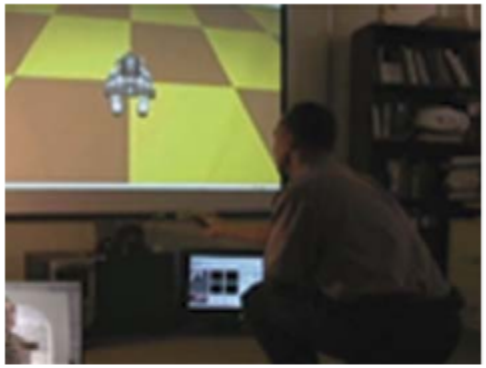
- Neurons are excitable cells that fire an action potential once a threshold voltage has been reached.
- This spike of electrical activity initiates the communication between neurons. Its effect is felt by all neurons connected to the one that spiked.

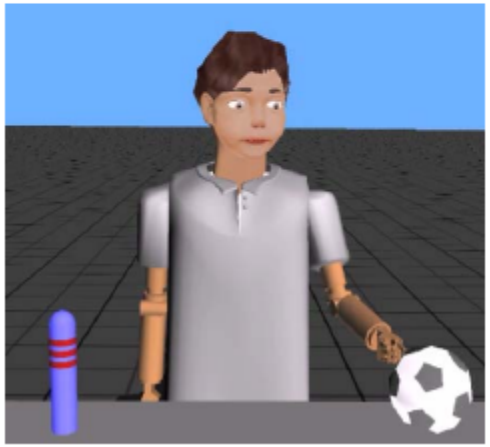




Introduction:
Neurorobotics and VNR







Introduction:
Neocortical Simulator

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Features:

- High-performance MPI-based parallel architecture
- Leaky Integrate-and-fire (LIF) neurons with conductance based synapses and Hodgkin-Huxley channels.
- Hebbian synaptic learning with Short-term plasticity, augmentation, and spike-timing dependent plasticity (STDP).
- Unique network mechanism for getting spiking information out and stimulus information in.

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NCSTools

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- Previous tools required intimate knowledge of both neuroscience and engineering.
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- Previous solutions lacked reusability.

NCSTools Design:

Software Engineering

Developed in C++ as a replacement for a package named Brainstem.

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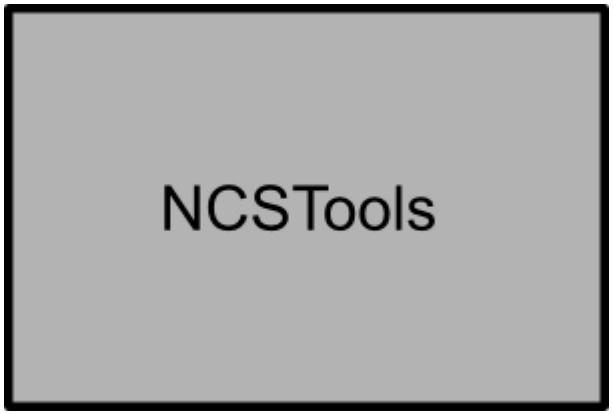
- Usability
- Extensibility
- Robustness
- Reliability

NCSTools Design:
Components



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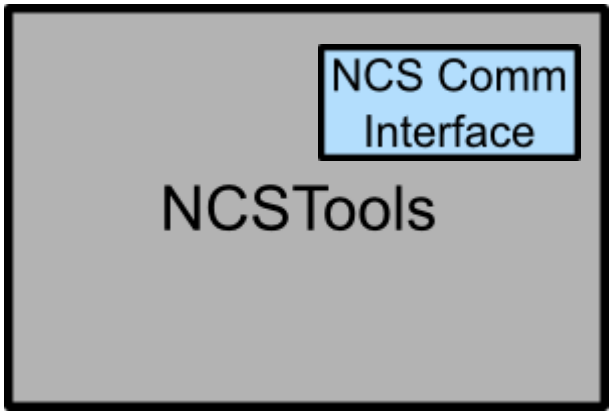

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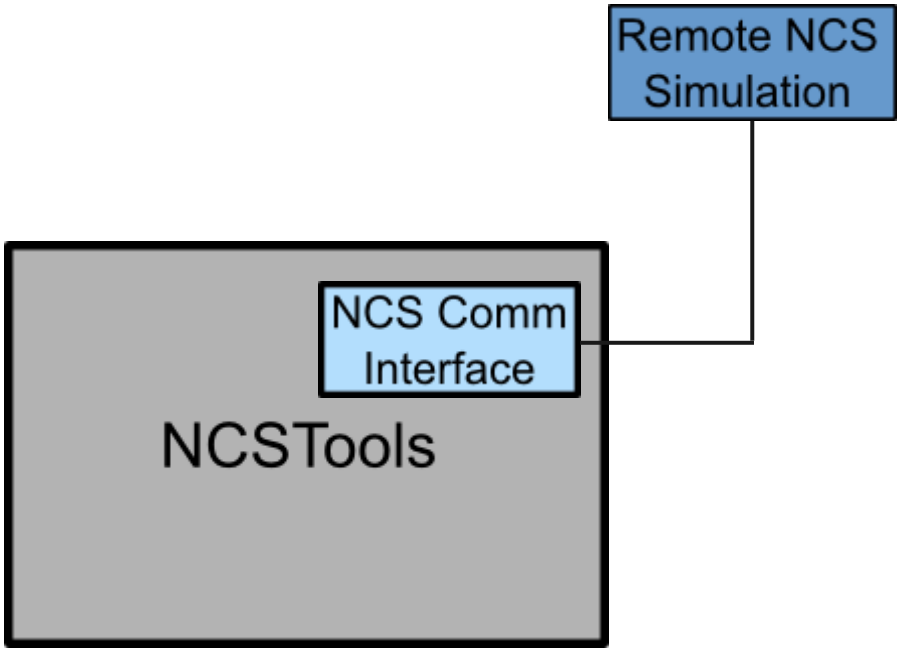

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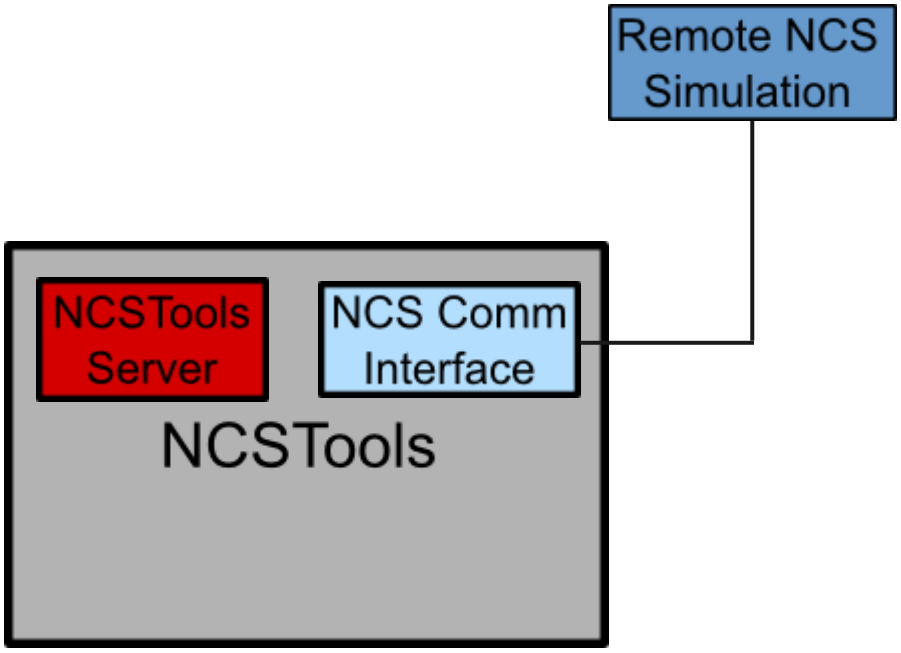

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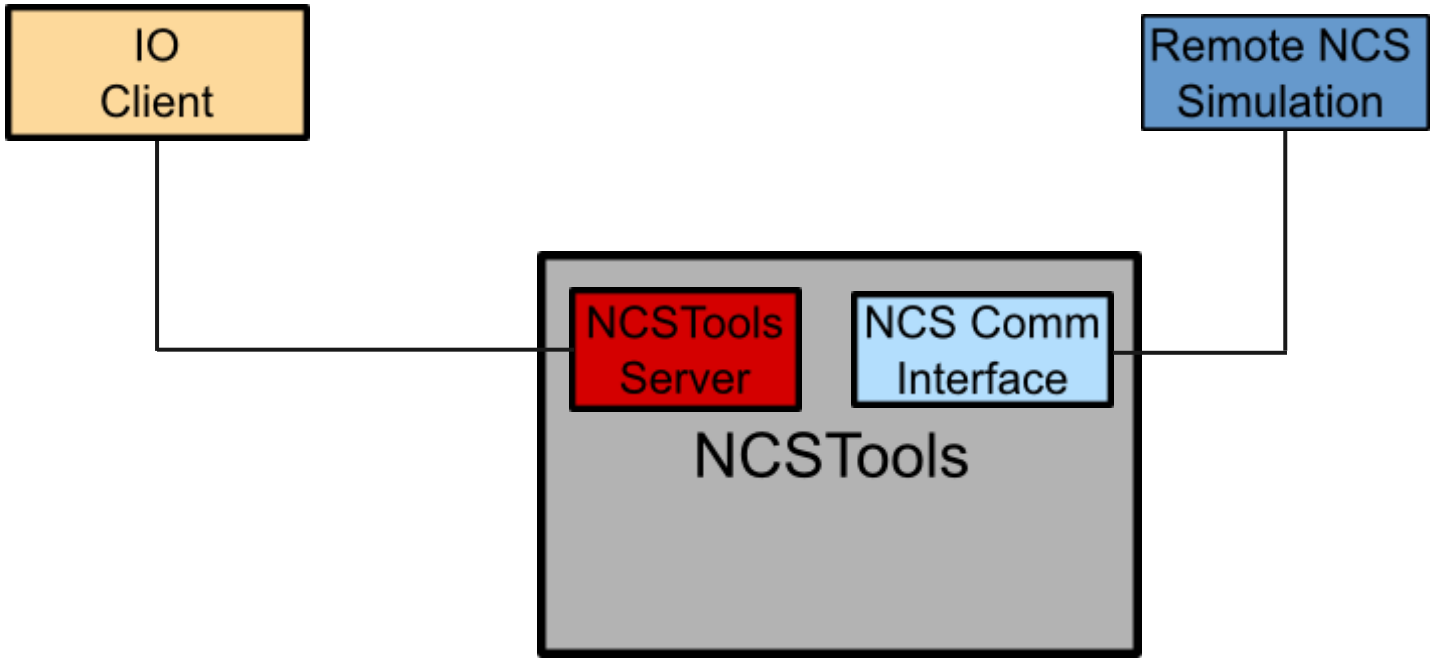

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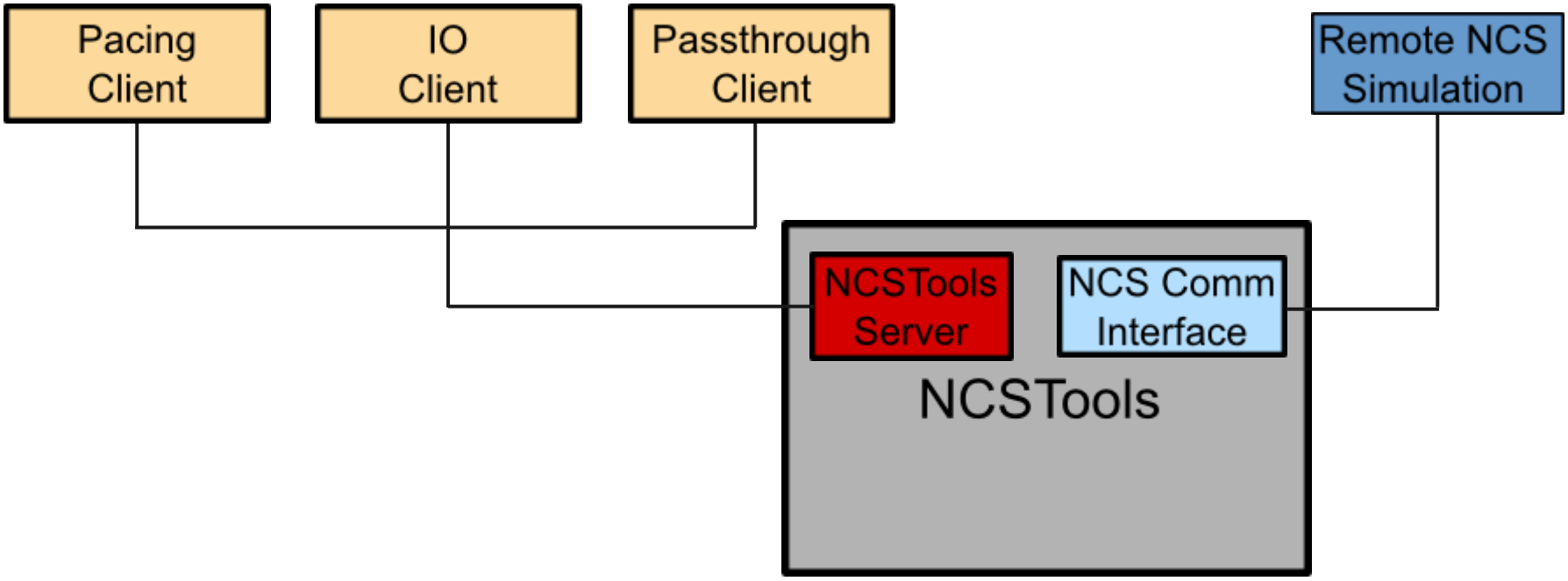

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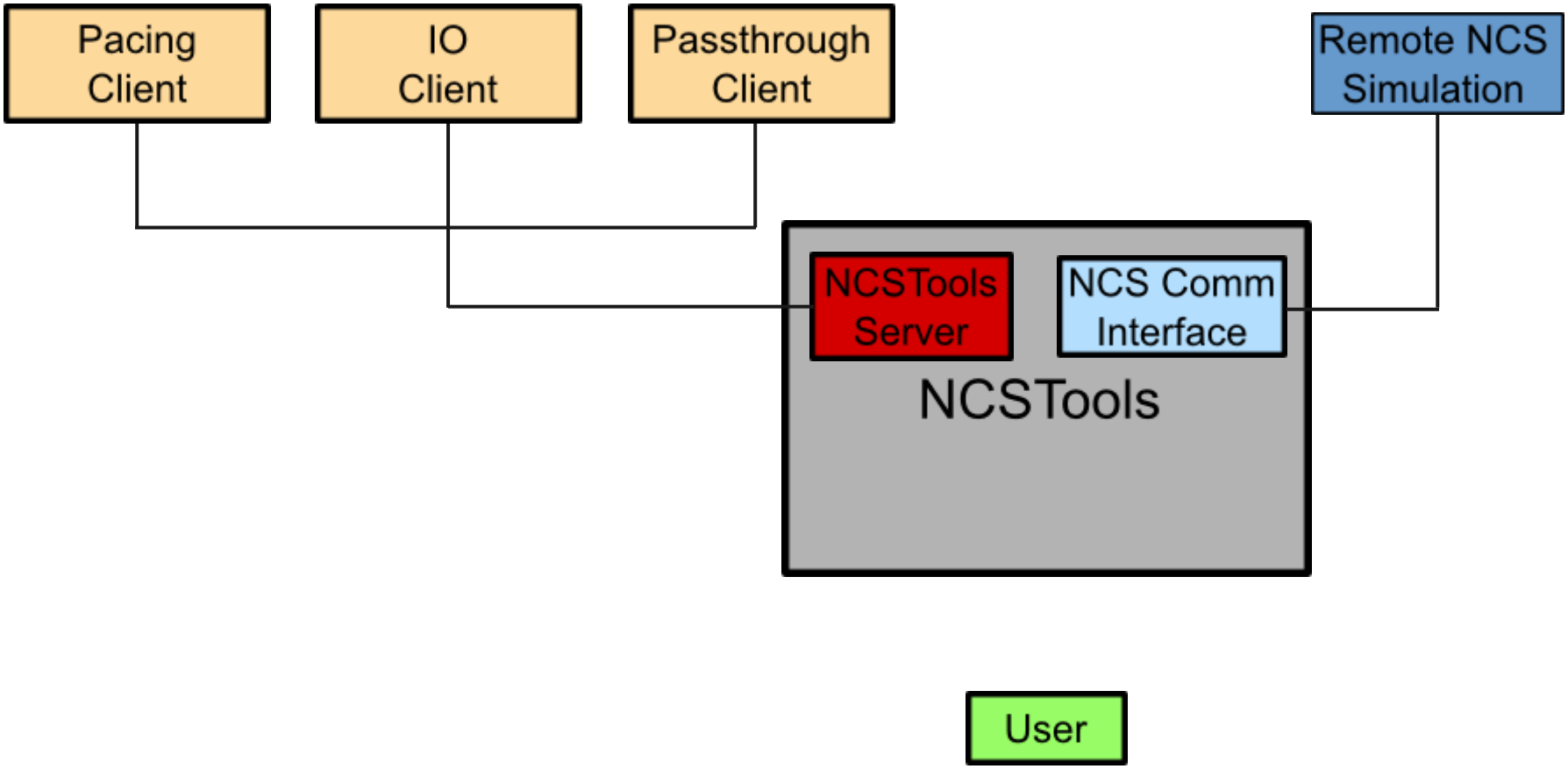

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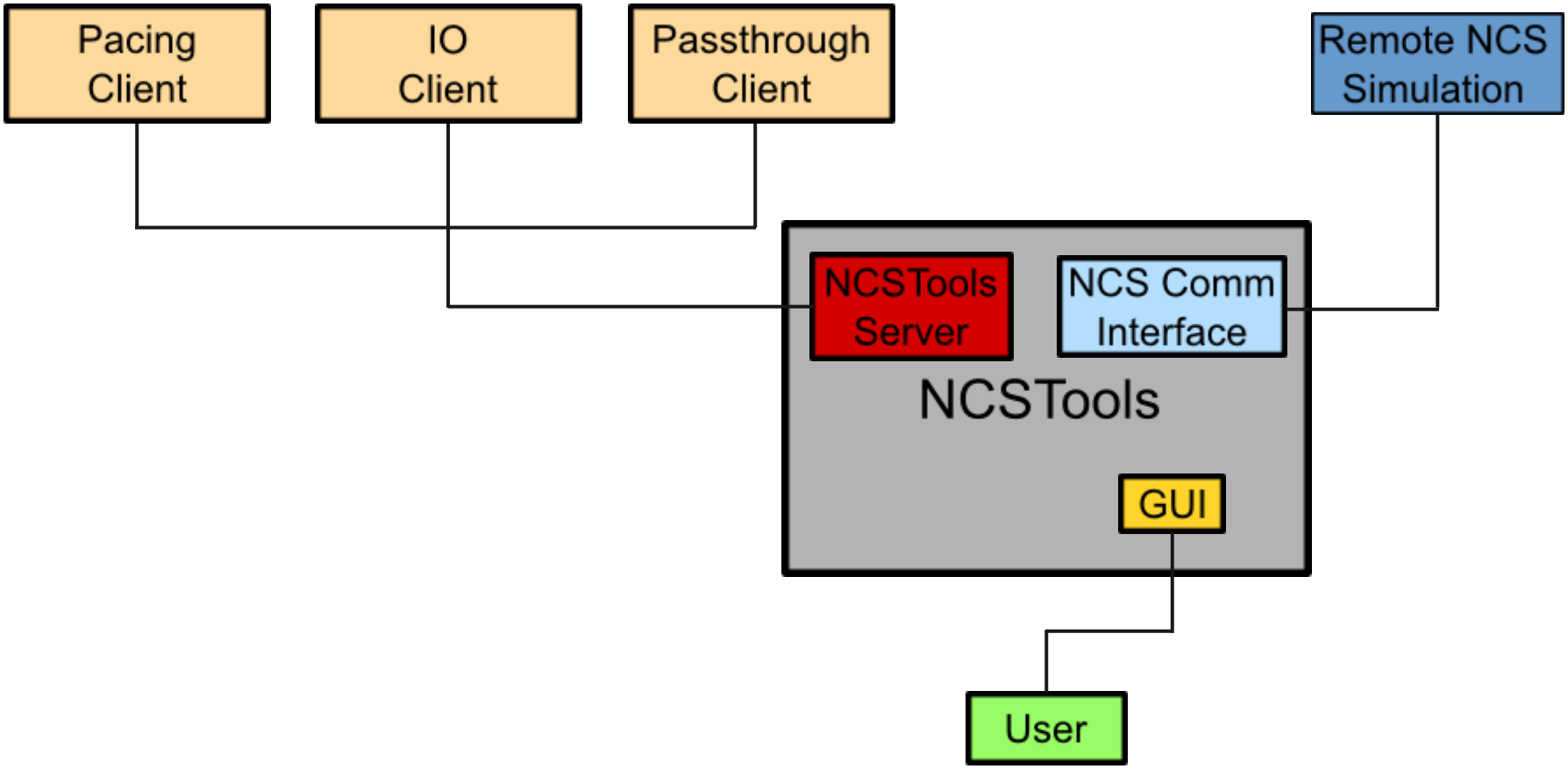

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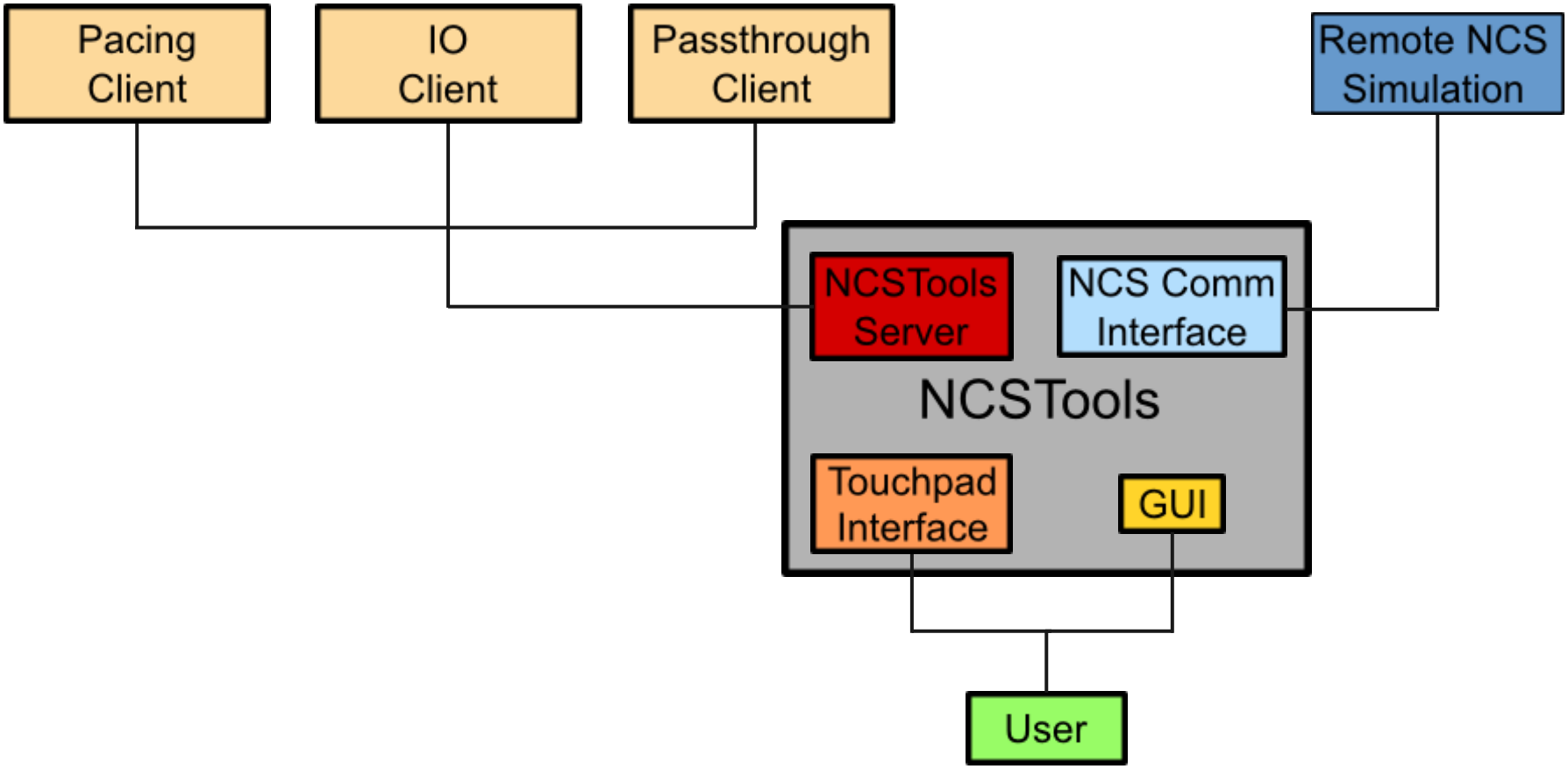

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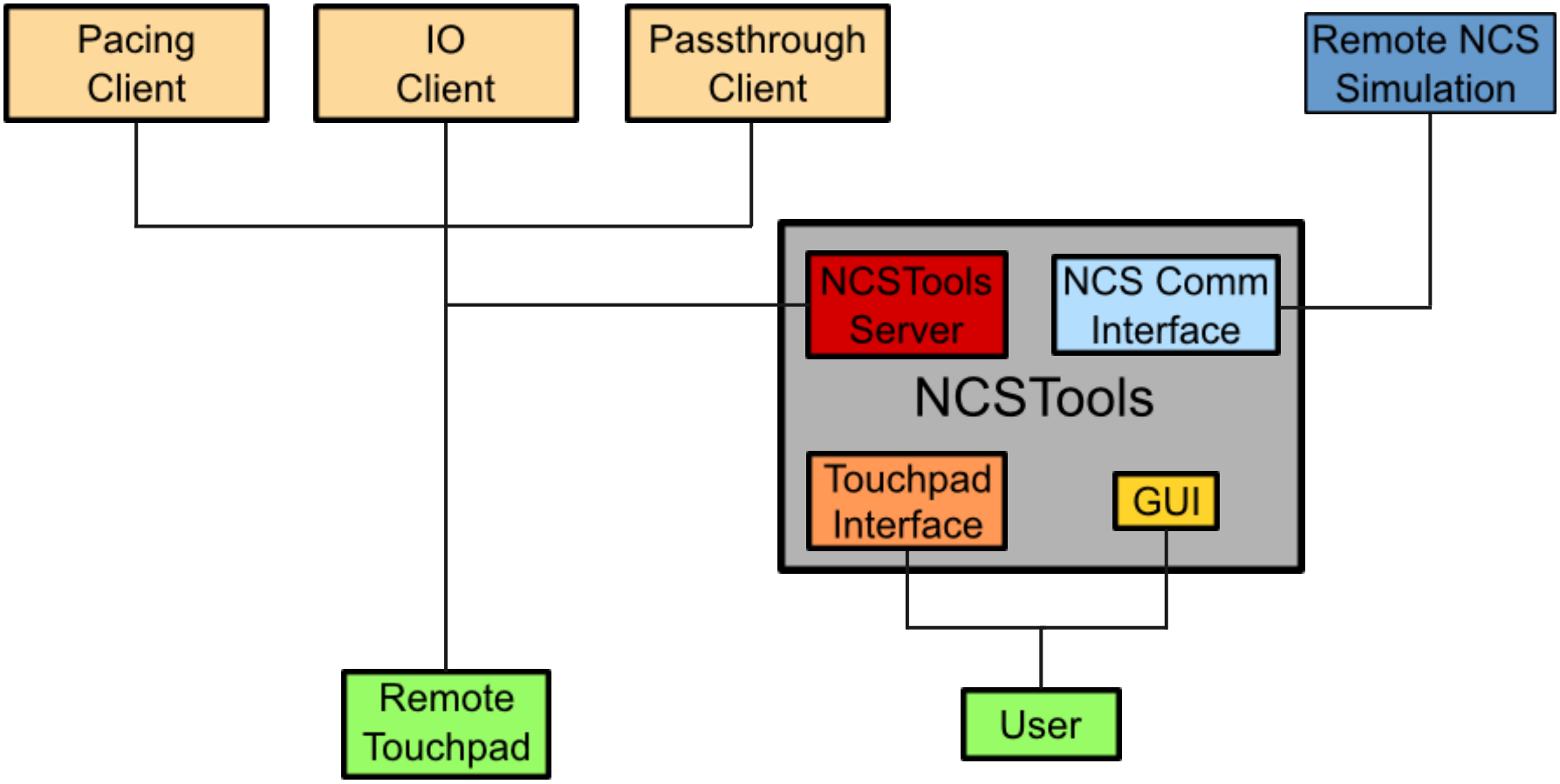

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Configuration Language

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This includes:

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- GUI
- User IO
- Data Processing

NCSTools Design:

Configuration Language

```
input:
{
  NCSReportCollection1: {
    num_reports = 500;
    # The total period of counting, includes
    # report collection and recovery.
    period = 500;
    # The number of reports.
    NCSReports = 2;
    type = "STANDARD";
    NCSReport1: {
      connection = "to_PMC1";
      command = "point_left";
      };
    NCSReport2: {
      connection = "to_PMC2";
      command = "point_right";
    };
    # Setup the plots for this group.
    plot = "YES";
    plotType = "BAR";
    plotname = "Motor Activity";
    tabIndex = 1;
    plotIndex = 1;
  };
};
```

NCSTools Design:
Configuration Language

```
output:
{
  NCSStim1: {
    type = "TIMED_OUTPUT";
    command = "saw_red";
    connection = "from_VC1";
    # The static output to send.
    output = "0.2000";
    # How many ticks between stim inputs.
    frequency = 50;
    # The number of times to repeat the input.
    num_outputs = 10;;
  };
  NCSStim2: {
    type = "TIMED_OUTPUT";
    command = "saw_blue";
    connection = "from_childbot_VC1";
    output = "0.0000";
    frequency = 50;
    num_outputs = 10;;
  };
};
```

NCSTools Design:

Inputs

Inputs are signals coming from NCS.

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- Spike Counts

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Two Types of Inputs

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Configurable GUI for plotting simulation information.

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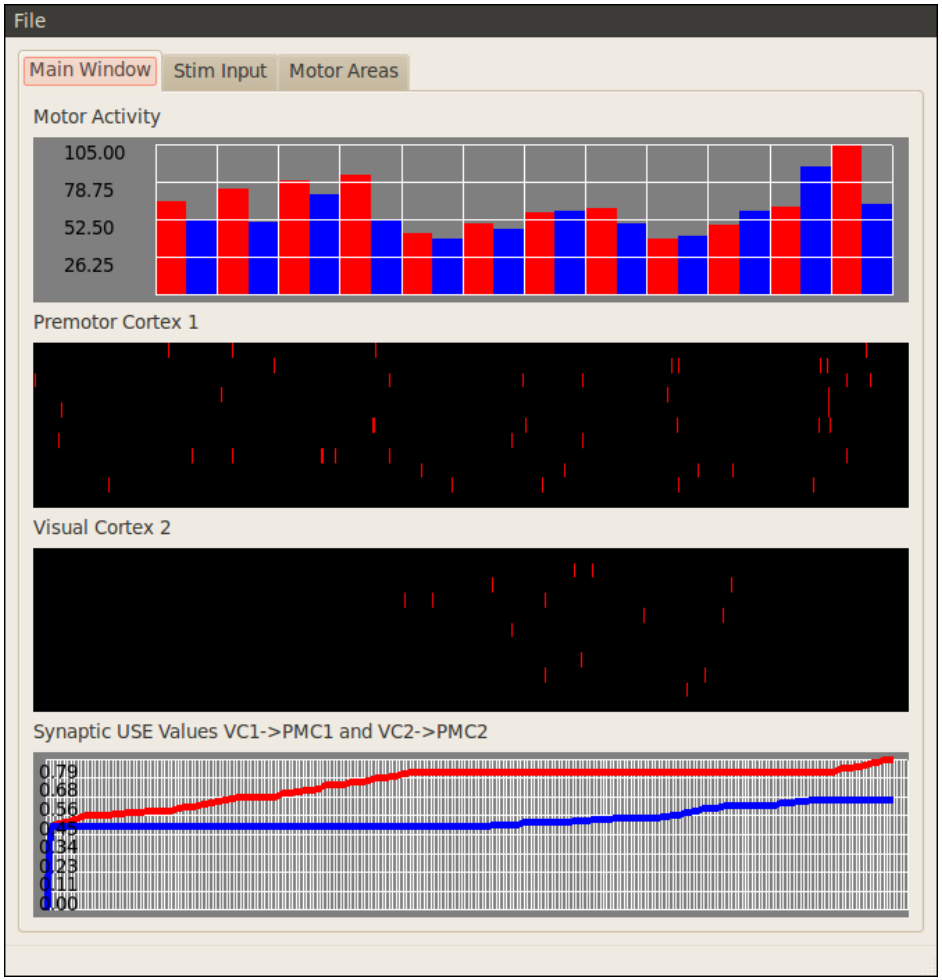

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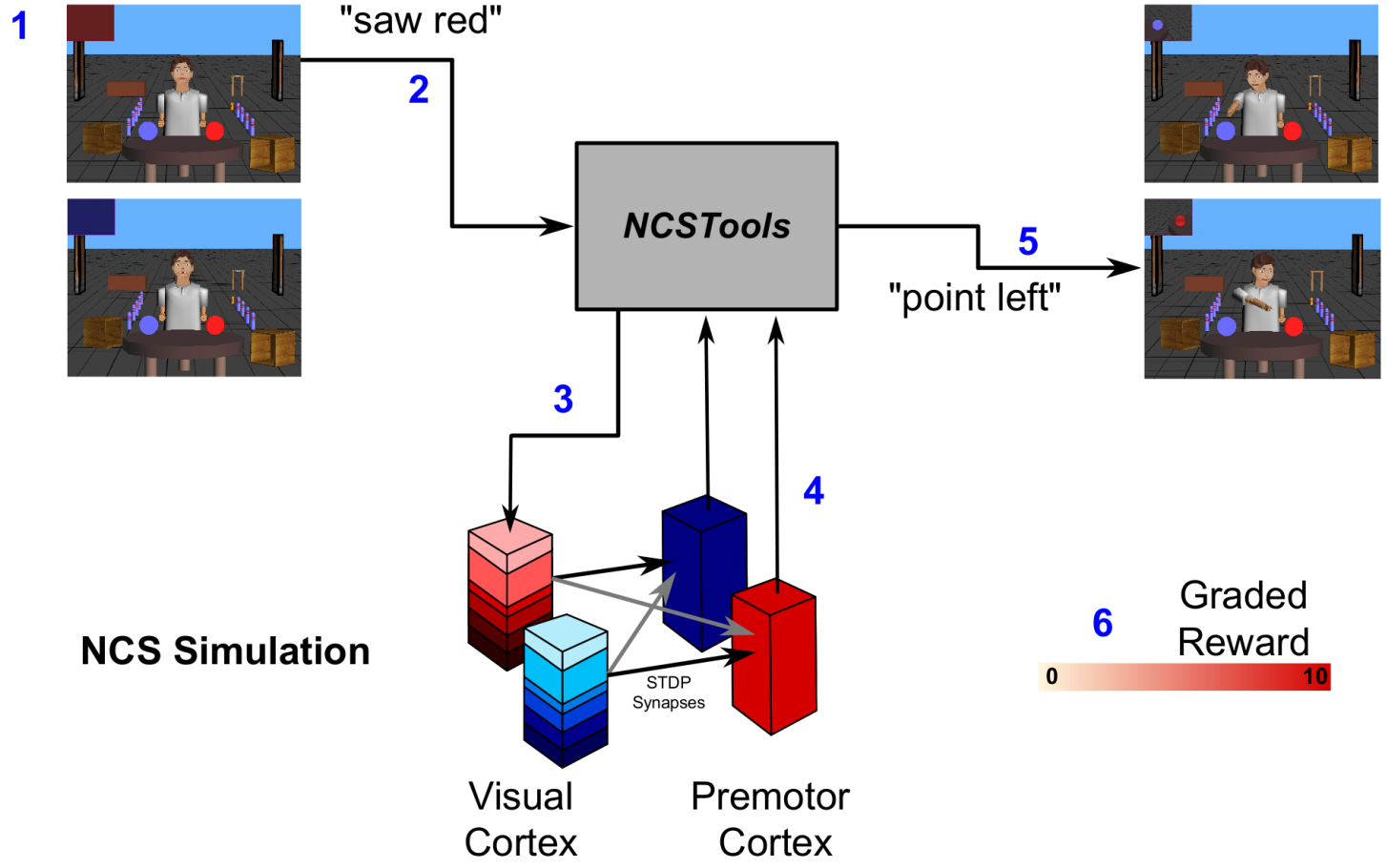
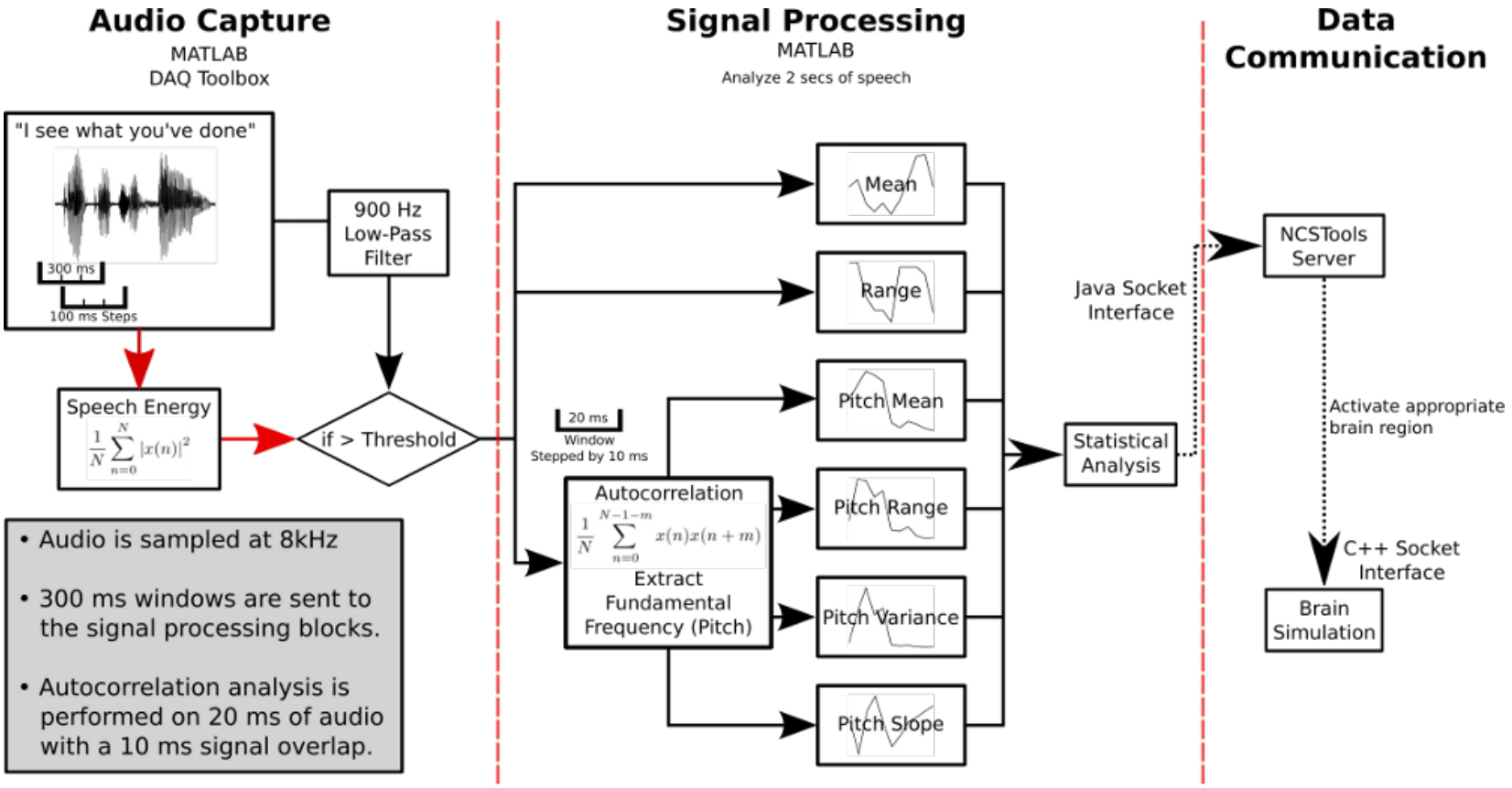
Example

Reward-Based Learning



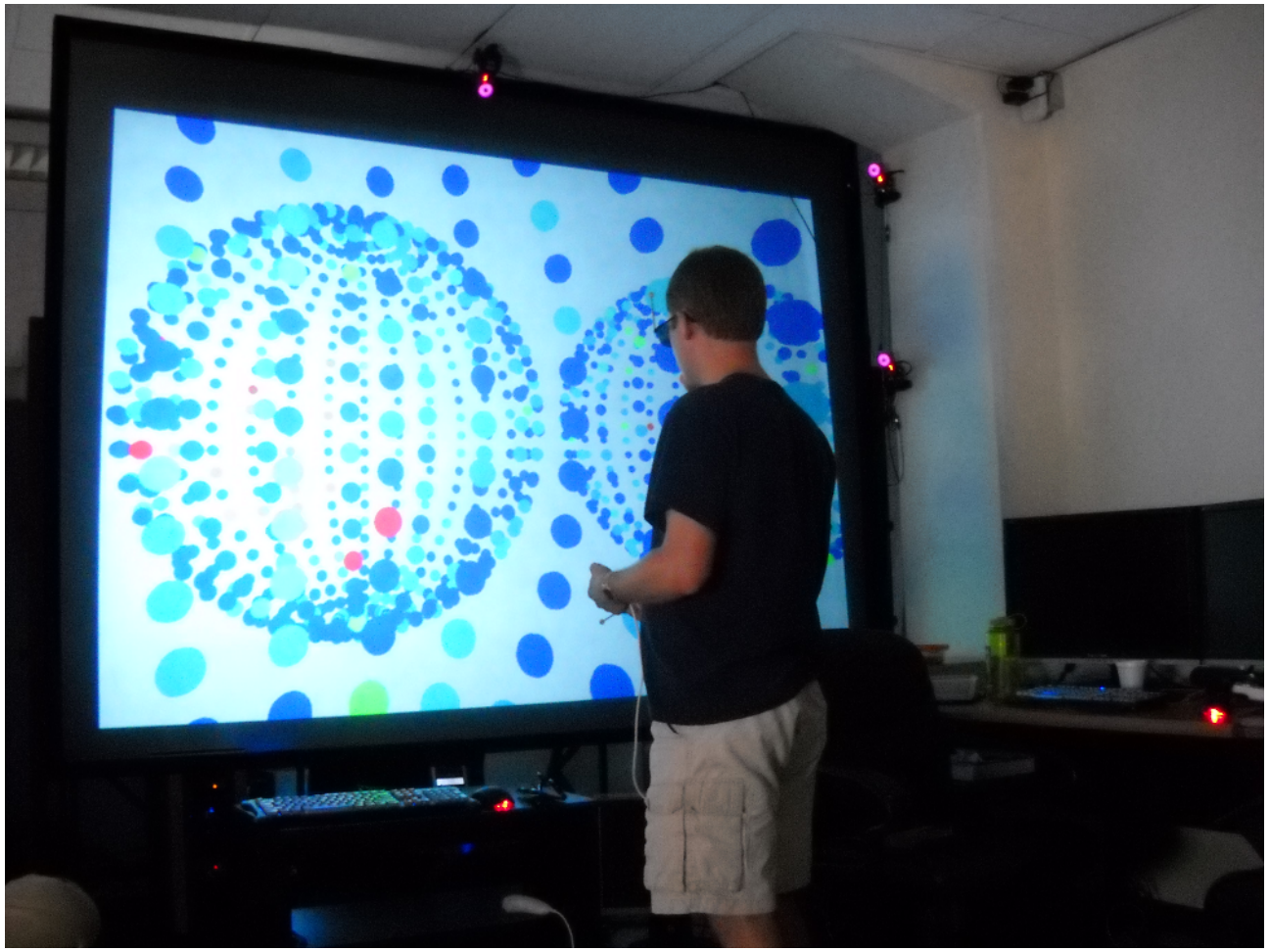
Example

Emotional Speech Processing



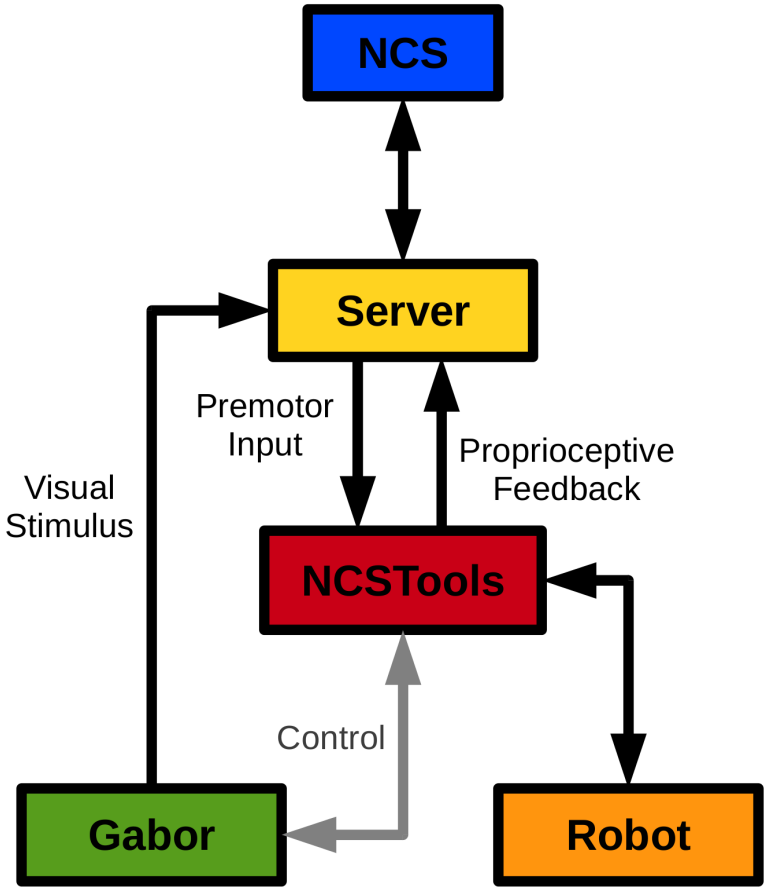
Example

Virtual Reality



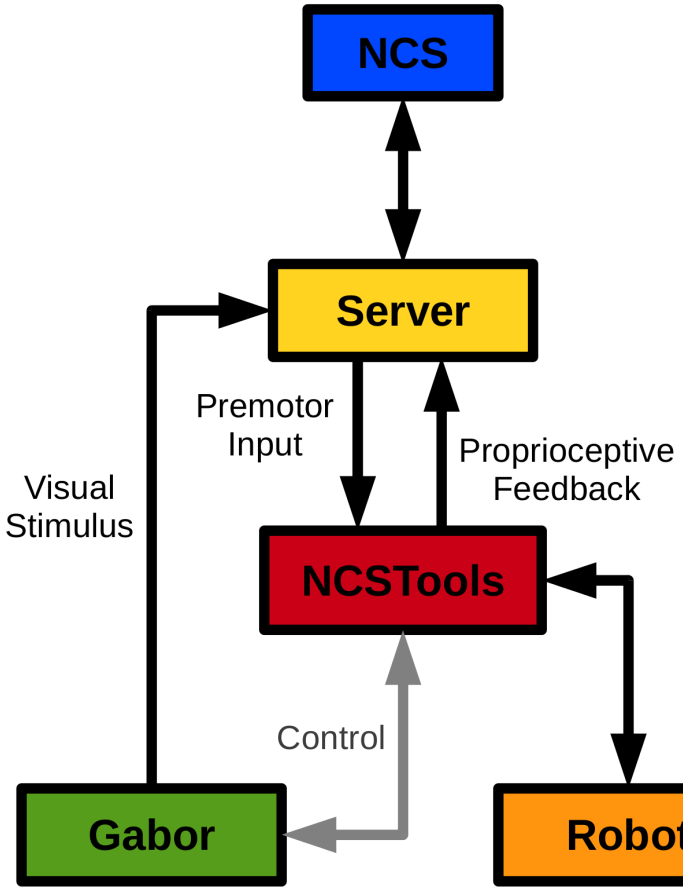
Example

Trust the Intent

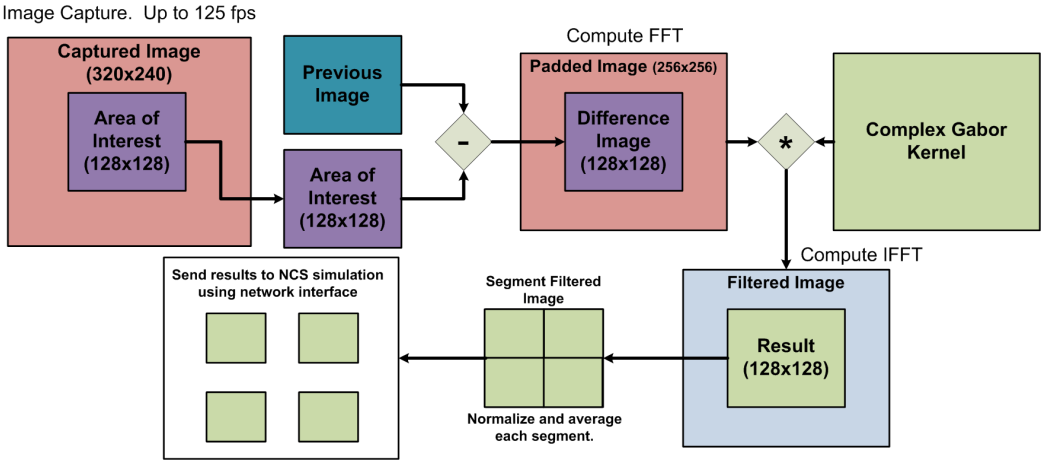


Example

Trust the Intent

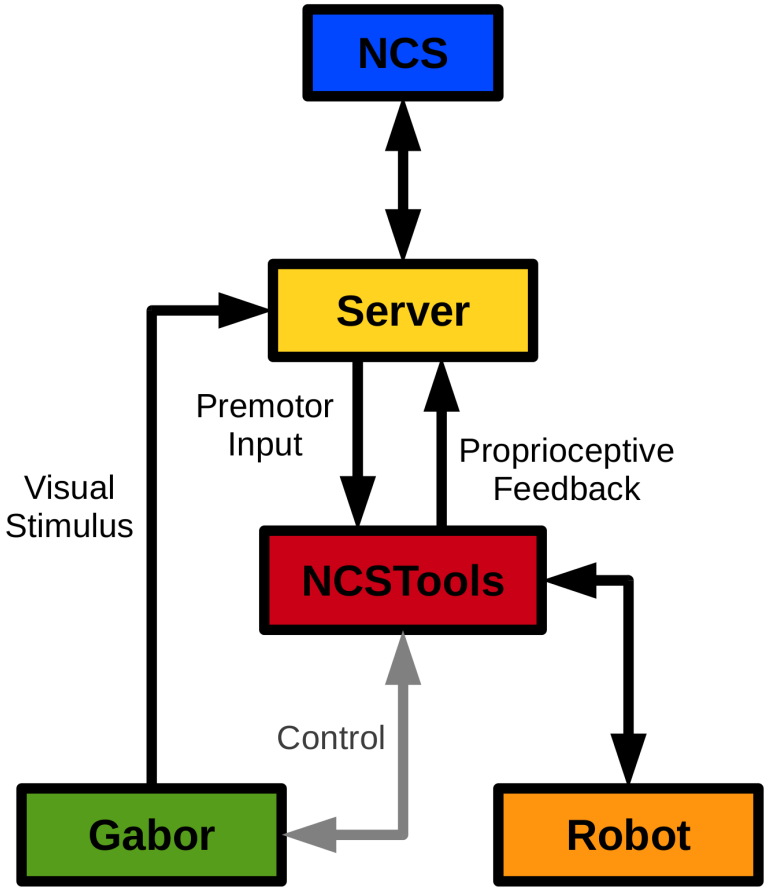


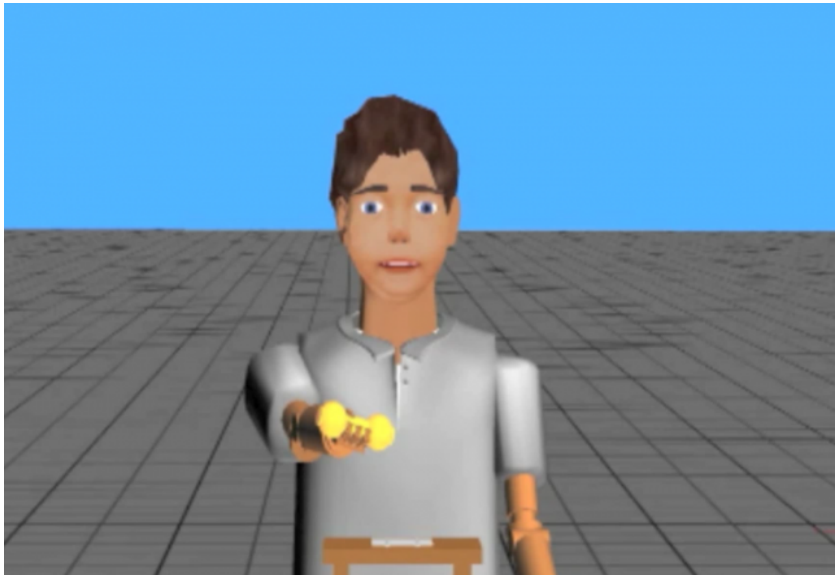
User is Captured by Gabor Filter Program:



Example

Trust the Intent





Robotic avatar sends proprioceptive information to NCSTools and receives movements back.

Example

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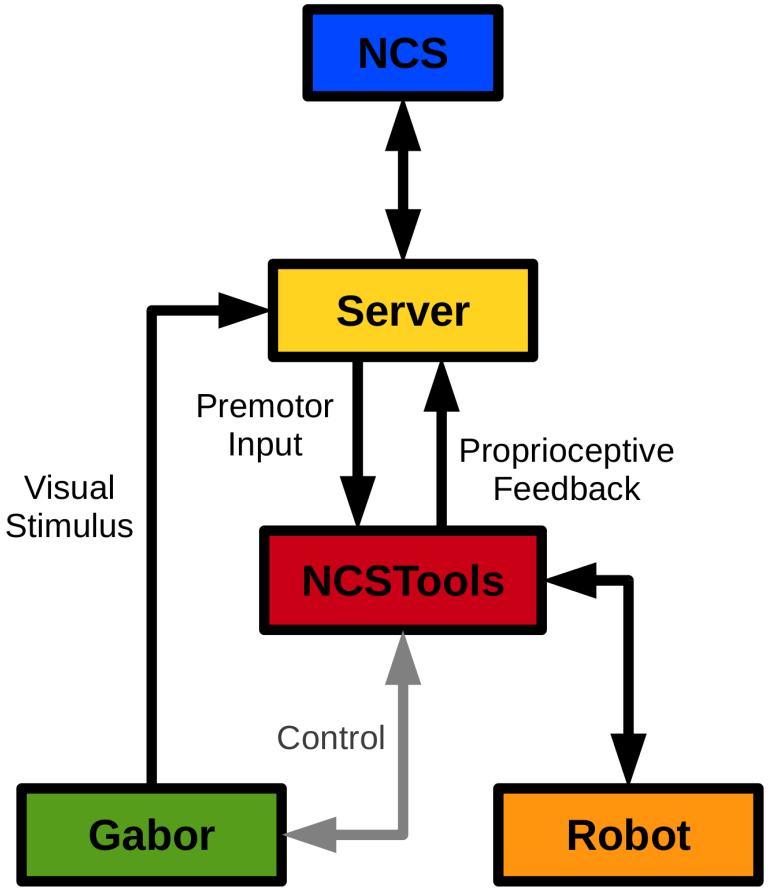

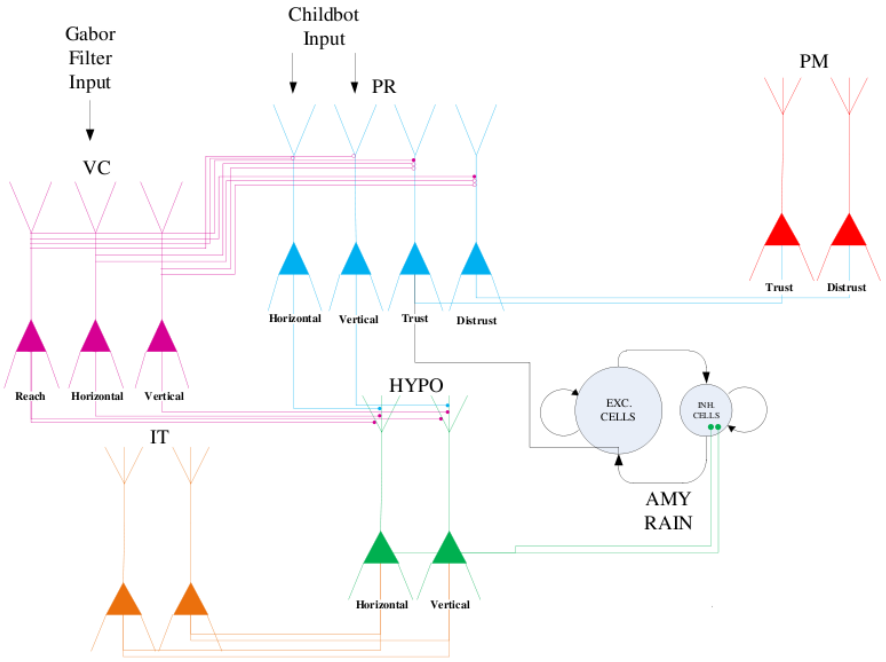

NCSTools sends stimulus information to NCS and received back neural activity.

Example

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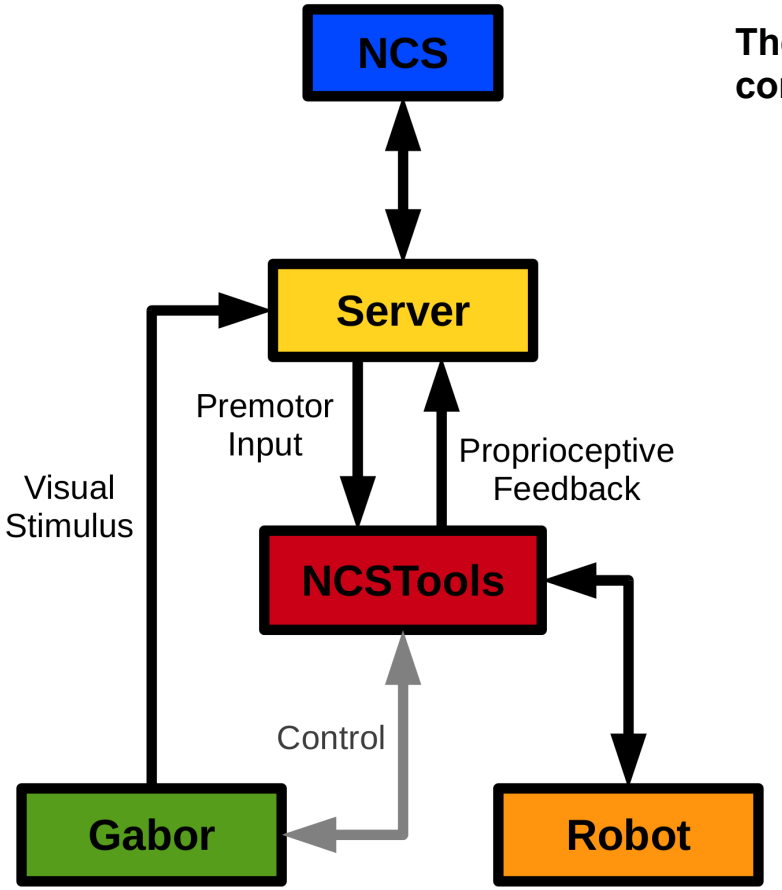
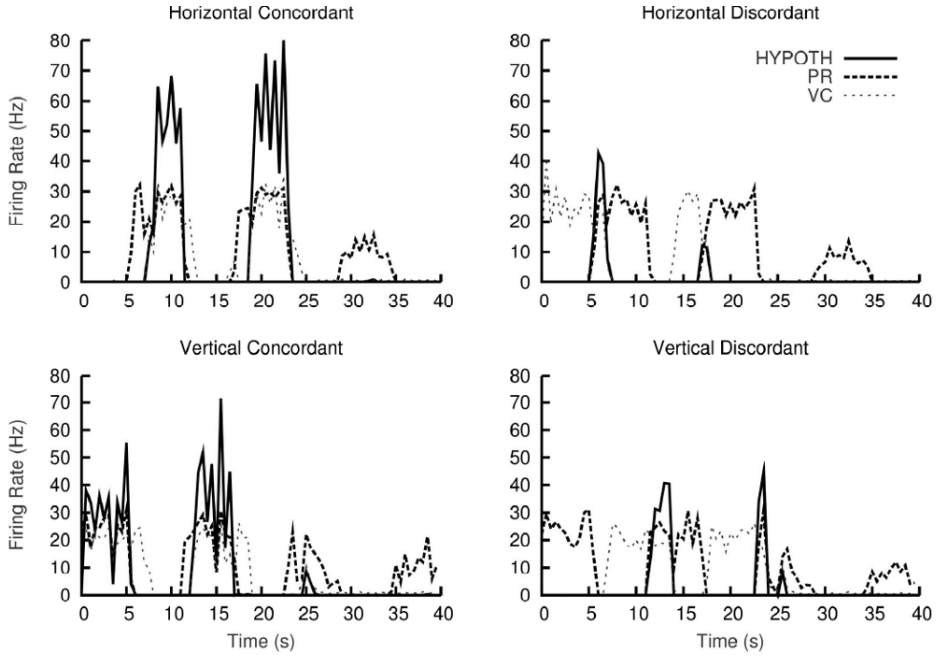


The information is processed based on the user configuration.



Example

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