Hanitu User Guide

For Hanitu V.1.4-r2

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1. Introduction

1.1. What is Hanitu

Hanitu is a simulation environment that simulates behavior and neural activity of user-designed virtual worms in a two-dimensional virtual world. In Hanitu, the users need to think deeply about how different components of a nervous system work together to achieve the ultimate goal of an animal – to survive in a changing environment

Hanitu is designed for graduate and undergraduate students who already acquired basic knowledge about computational neuroscience and who would like to apply what they learned to addressing some of the system-level questions in neuroscience.

1.2. System requirements

For general users: The current version of Hanitu is compatible with and has been tested on Ubuntu Linux. The Hanitu software package comes with pre-compiled executables for Linux and contains Java SE Runtime Environment (java 1.8) already.

For developers: Hanitu (the virtual world) and Flysim (the simulator) are written in C++ with C++11 library and compiled with gcc 4.8. The GUI is written in Java.

1.3. Installation

The Hanitu system does not need installation. The users only need to download the entire contains of the software package (32-bit or 64-bit) into a local hard drive. The users many need to set the program files (*.out) as executable if they are not (using the “chmod” command).

1.4. The content of the Hanitu software package

The Hanitu software package contains the following top-level directories:

- **bin**：Containing scripts which can be executed in the terminal.
- **jre1.8**：Java Runtime Environment (JRE).
- **lib**：Containing precompiled executable program files of Hanitu (Hanitu.out) and Flysim (flysim.out) and compressed package of GUI interface software (HanituToolSet.jar).
- **share**：Containing three sub-folders：
  - script：Sample script files for running Hanitu or for data analysis.
  - sample：Sample circuit (*.ccg) and virtual world (*.wcg) configuration files.
  - documents：User guide, manual or other documents.

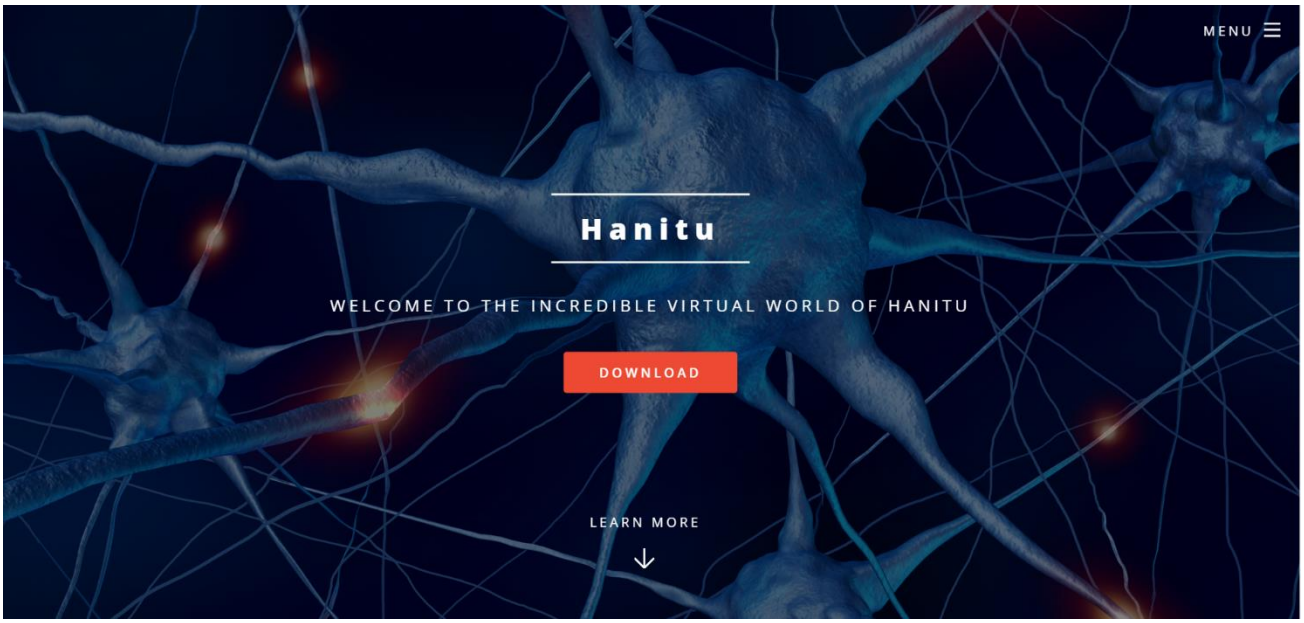
The Hanitu software package contains several executables, scripts and configuration files:

- **HanituGUI**：**The main program users need to run.** The users can run it in the terminal or by clicking on it in a file manager. All the major functions of Hanitu (virtual world design, circuit design, simulation and virtual world visualization) are included in this GUI.
- **bin/hanitu_world**：The script brings up a GUI for configuring the virtual world. See 3.1.GUI for virtual world configuration setting for GUI description. This script is integrated into HanituGUI, but users can run the script independently if they need to.
- **bin/hanitu_circuit**：The script brings up a GUI for designing virtual worm circuits. See 3.2.GUI for designing virtual worm for GUI description. This script is integrated into HanituGUI, but users can run the script independently if they need to.
- **bin/hanitu_plot**：This script brings up a GUI and display movement of the worms by reading Locations.txt (See 4.1.Locations.txt) that was saved previously. See 3.3.GUI for display for GUI description. This script is integrated into HanituGUI, but users can run the script independently if they need to.
- **bin/hanitu_run**：Run Hanitu.out, Flysim.out and plot. This program is integrated in HanituGUI. But if the users want to skip world design and circuit design by performing the simulation directly, they can execute this program.

- **bin/hanitu_concentration** ： The script calculates single molecule diffusion concentration of food or toxicants in different distance. This script is not included in HanituGUI.
- **bin/hanitu_filter** ： The script is used for post-simulation analysis. It extracts information from Spike.txt (See 4.2.Spike.txt) such as spiking time and neuron ID according to specific user ID, virtual worm ID and type of neurons(sensory、motor、body). This script is not included in HanituGUI.
- **bin/hanitu_firingrate**：The script is used for post-simulation analysis in conjunction with hanitu_filter. It calculates firing rate based on the output data generated by hanitu_filter. This script is not included in HanituGUI.
- **bin/hanitu_tool**：The main script called by HanituGUI. Users do not need to interact with this script.
- **lib/Hanitu.out**：The main program of Hanitu. The users do not need to interact with the program.
- **lib/flysim.out**：The neural network simulator used in Hanitu. The users do not need to interact with the program.
- **share/script/template.sh**：A sample script for post-simulation analysis.
- **share/sample/4neurons.ccg**、**direct_connection.ccg**、**simple_decision.ccg**、**simple_decision-npy.ccg**、**champion-v.1.2.ccg**、**first_runner_up-v.1.3.ccg**：Three sample worm configuration files. Each file contains parameters used to define the neural circuit of a worm species. The users can edit files directly. See Appendix A.2.Circuit configuration files for details.
- **share/sample/world_config.wcg**：A sample configuration file for the virtual world. See Appendix A.1. Virtual world configuration file for details.
- **Hanitu Simple Guide V.1.4.pdf**：This Hanitu user guide.

1.5. Official website

The official website is at http://hanitu.net.



2. How to run Hanitu

2.1. Using GUI

1. The users can use the GUI (HanituGUI) to edit virtual world configuration files (*.wcg, see Appendix A.1.Virtual world configuration file for details) and virtual worm circuit configuration files (.cgg, see Appendix A.2.Circuit configuration files for details). The users can also use the GUI to lunch simulations and view the virtual world with the worm survival games in action. There are three methods for executing:
   a. Double-click on the HanituGUI icon in a file manager.

   b. Enter following command in the terminal[1]
   ```
   ./HanituGUI
   ```

   c. Move to “bin” folder and enter command below under the ./bin subdirectory in the terminal
   ```
   ./hanitu_world [FILE]
   ```
   [FILE] should point to a world configuration file.

2. To perform simulations and to display virtual worm movements only, simply enter the following command under the ./bin subdirectory
   ```
   ./hanitu_run [FILE]
   ```

   [FILE] should point to a world configuration file.
   The users need to make sure that the virtual world configuration file (.wcg，default is world_config.wcg) and the corresponding virtual worm circuit configuration files (.ccg) are presented in the same directory.

3. The users can enter the following command to execute GUI for only displaying virtual worm movements based on the data previously stored in a location files (See 4.1.Locations.txt).
   ```
   ./hanitu_plot [Location file]
   ```

[1] The users can get help information through adding “`-h`” behind the commands.

2.2. Performing Hanitu simulations directly (without GUI)

First, open two terminals. Run Flysim (under /lib) in one terminal[2]:

```
./flysim.out -daemon 8889
```

and run Hanitu (under /lib) in the other terminal:

```
./Hanitu.out -w [world config FILE]
```

The users need to make sure that virtual world configuration file (.wcg，default is world_config.wcg) and corresponding virtual worm circuit configuration files (.ccg) are presented in the same directory.

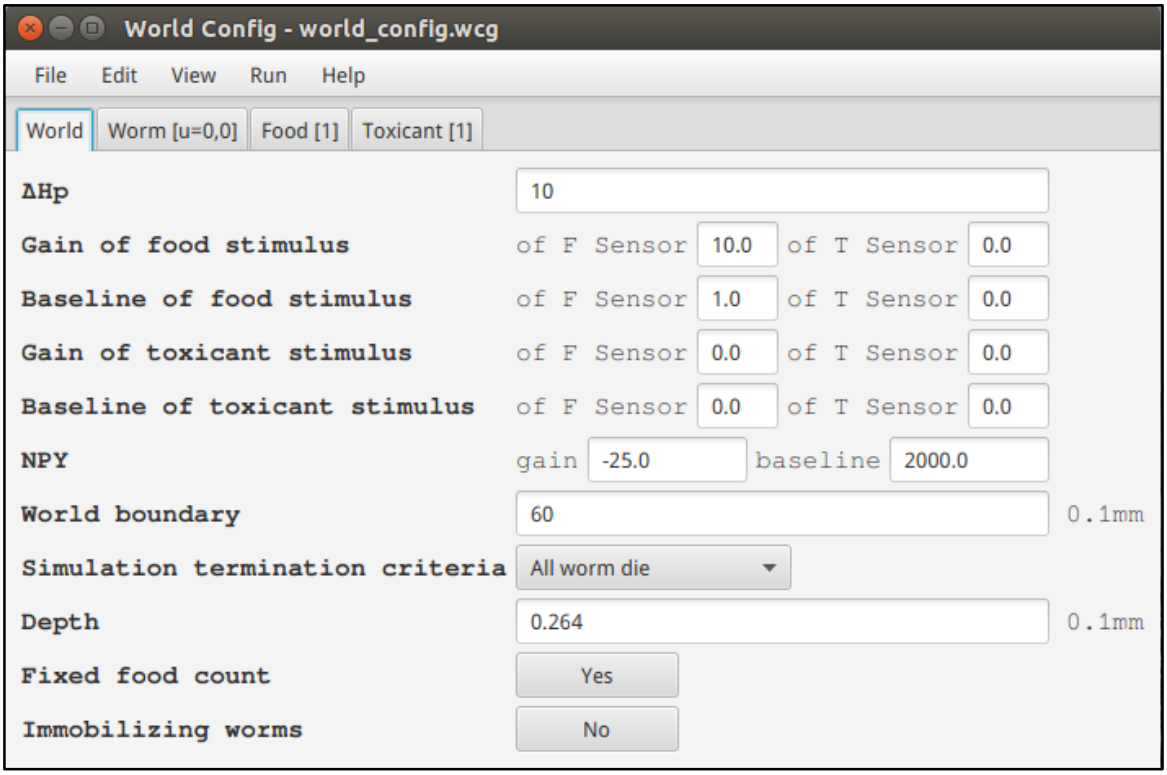
The users should restart Flysim before running Hanitu again.

[2] The users can get more function information by adding "`-h`" behind commands.

3. How to use the GUI

3.1. Setting the virtual world in the main GUI

After executing HanituGUI, the users will see the following main GUI which is used for setting parameters of the virtual world and related parameters.



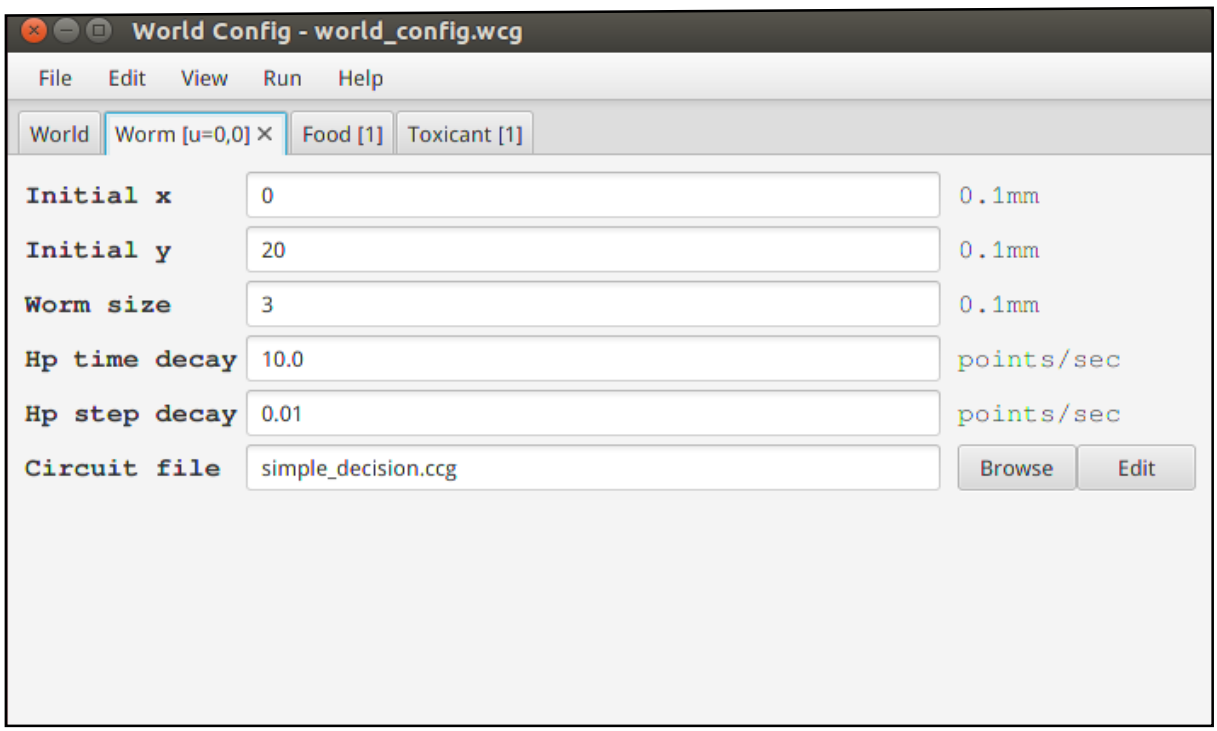
Parameters in GUI	Corresponding parameters in configuration files[3]	Description
ΔHp	Nutrient	The energy level increased or decreased when a worm touches a food or a toxicant, respectively
Gain of food stimulus of F Sensor	GainFF	Define the relation between the sensory neuron input rate and the odorant concentration for the food stimuli with respect to the food sensory neurons. GainFF defines the gain and BaselineFF defines the baseline[4].
Baseline of food stimulus of F Sensor	BaselineFF	

[3] The names of parameters in all configuration files are case insensitive.

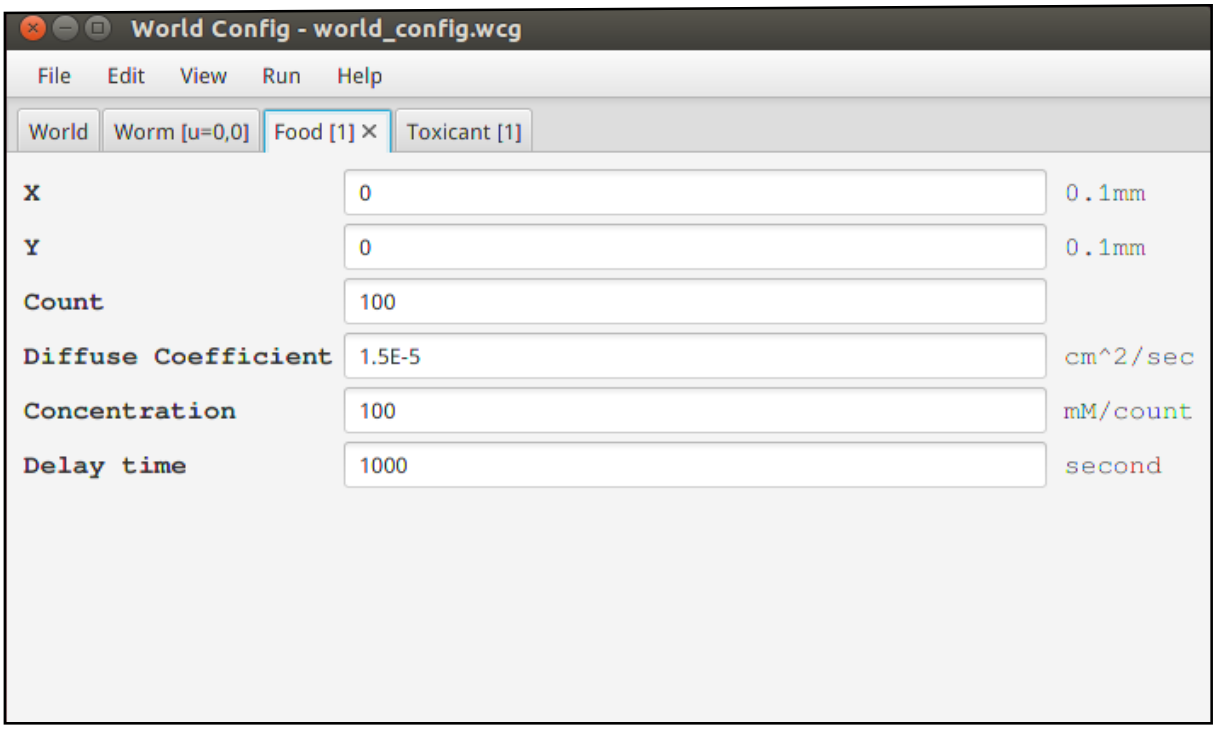
[4] **Equation**：$\text{firing rate(Hz)} = Gain \times [\text{Odor}](\text{mM}) + \text{Baseline}$,

$[\text{Odor}]$ means concentration of molecule (mM). The names of parameters in all configuration files are case insensitive.

Parameters in GUI	Corresponding parameters in configuration files	Description
Gain of food stimulus of T Sensor	GainFT	Similar to GainFF and BaselineFF but for the food stimuli with respect to the toxicant sensory neurons
Baseline of food stimulus of T Sensor	BaselineFT	
Gain of toxicant stimulus of F Sensor	GainTF	Similar to GainFF and BaselineFF but for the toxicant stimuli with respect to the food sensory neurons
Baseline of toxicant stimulus of F Sensor	BaselineTF	
Gain of toxicant stimulus of T Sensor	GainTT	Similar to GainFF and BaselineFF but for the toxicant stimuli with respect to the toxicant sensory neurons
Baseline of toxicant stimulus of T Sensor	BaselineTT	
Gain of NPY	GainNPY	Similar to GainFF and BaselineFF but for the ghrelin stimuli with respect to the NPY neuron
Baseline of NPY	BaselineNPY	
World boundary	Boundary	The boundary (between -50 and 50 for both x and y) of the virtual world. The unit is 0.1mm.
Stimulation termination criteria	Type	Criteria for the simulation termination. Type=0, terminated when all worms die. Type=1, terminated when a worm first touches a food or a poison.
Depth	Depth	Height of the world. Used for calculating the odorant concentration. Do not alter.
Fixed food count	CountMode	Do not change this parameter. It tells the program that the amount of food in each food source is unlimited.
Immobilizing worms	Fixed	Fixing location of virtual worm or not. 1 for fixing and 0 for not. A worm with fixed location is useful for the testing purpose.



Parameters in GUI	Corresponding parameters in configuration files	Description
Initial x	InitialX	Worm's initial location in x and y. The unit is one step (0.1mm) of the worm.
Initial y	InitialY	
Worm size	Wormsize	Radius of the worm. (0.1mm)
Hp time decay	Time_decay	Energy level decay per second. (Initial value = 100)
Hp step decay	Step_decay	Energy level decay per step of the worm
Circuit file	Filename	The circuit configuration file of the worm

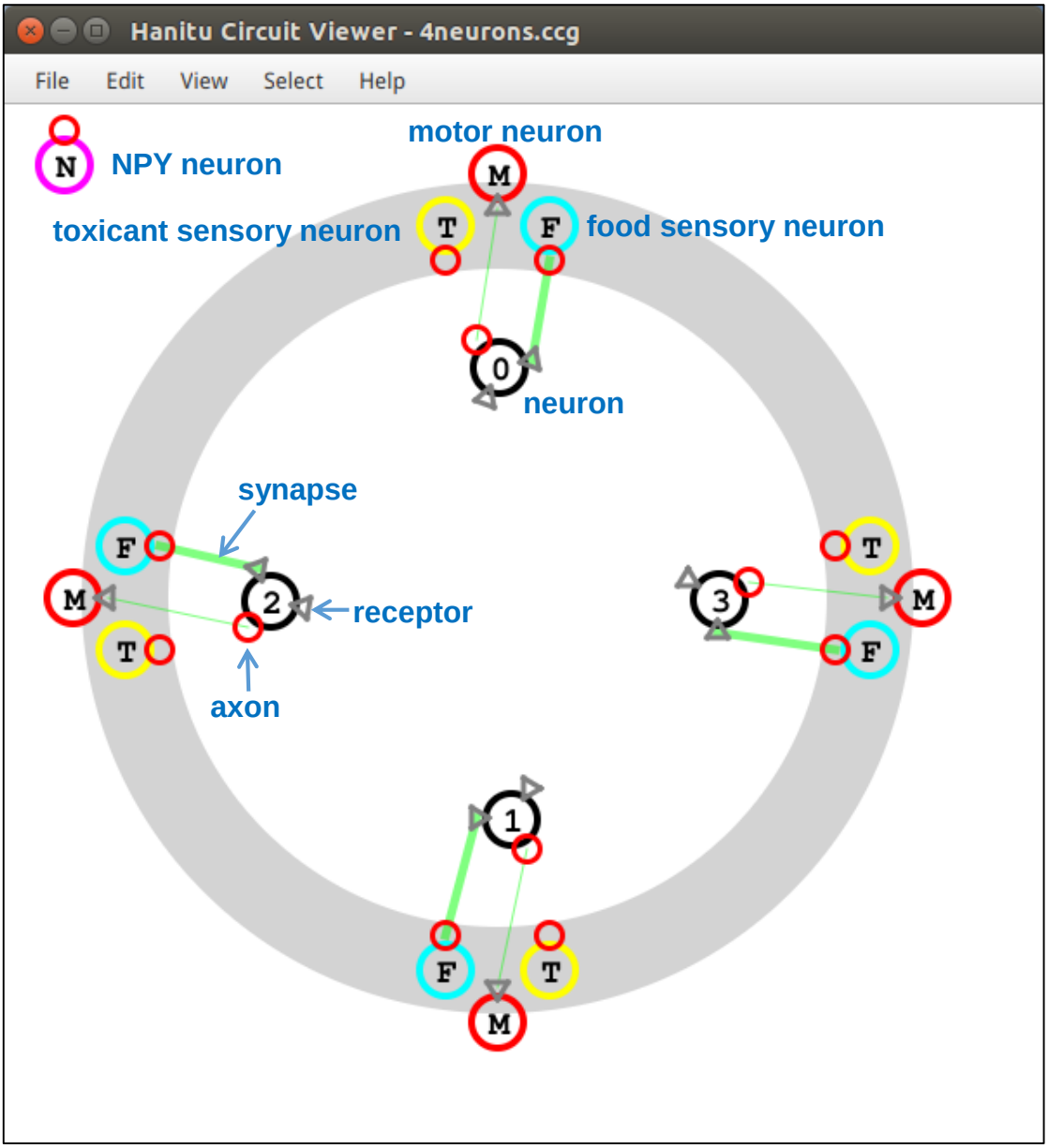


Parameters in GUI	Corresponding parameters in configuration files	Description
X	X	The location (in 0.1 mm) of the food source
Y	Y	
Count	Count	The amount of foods in each food source
Diffuse Coefficient	Diffuse	The diffusion constant of the food molecule $cm^2/_{sec}$
Concentration	Concentration	The concentration of the food molecule $(\mathrm{mM/count})$ at the food source for each food count.
Delay time	Delay_time	The virtual worm simulation starts with a delay after the foods are placed in the assigned locations. This parameter specified the delay time (in 0.1 msec)

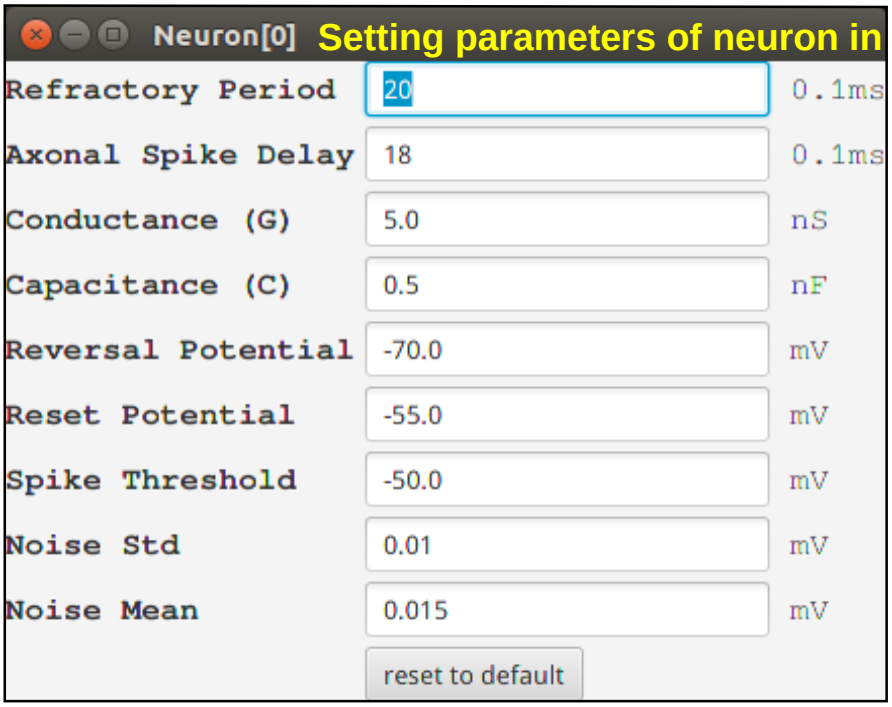
The GUI and parameters for toxicants are the same with those for foods.

3.2. Designing the virtual worm neural circuits

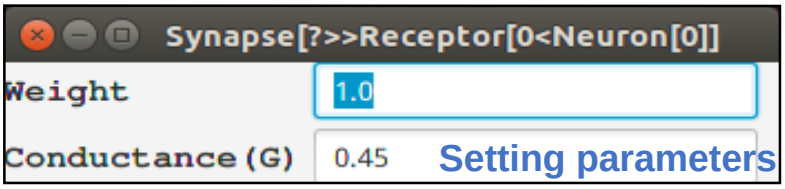
The user can edit the neural circuit of a giving worm in a GUI shown below. The GUI can be brought up by clicking the “Edit” button in a “Worm” tab in the virtual world GUI described in 3.1. In this GUI, the users can add new neurons by right-clicking. The small red circle on each neuron indicates an outgoing axon and the triangle indicates a receptor targeted by the axon from an upstream neuron. The users can connect two neurons by left-clicking on a red circuit of a source neuron and right-clicking on a triangle target on a target neuron.



The users can set parameters of a neuron by selecting (left-click) it and press “I”, which brings up a GUI as shown below.

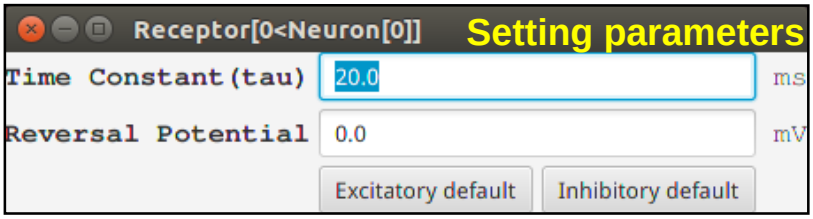


Parameters in GUI	Corresponding parameters in configuration files	Description
Refractory Period	Refperiod	Refractory period (timestep = 0.1 ms)
Axonal Spike Delay	Spikedelay	Spike delay (timestep = 0.1 ms)
Conductance (G)	G	Membrane leak conductance (ns)
Capacitance (C)	C	Membrane capacitance (nF)
Reversal Potential	NRevPot	Membrane reversal potential (mV)
Reset Potential	ResetPot	Reset Potential (mV)
Spike Threshold	Threshold	Spike threshold (mV)
Noise Std	std	Standard deviation of the membrane noise (current).
Noise Mean	mean	Mean of the membrane noise (current).



Setting parameters of synapse

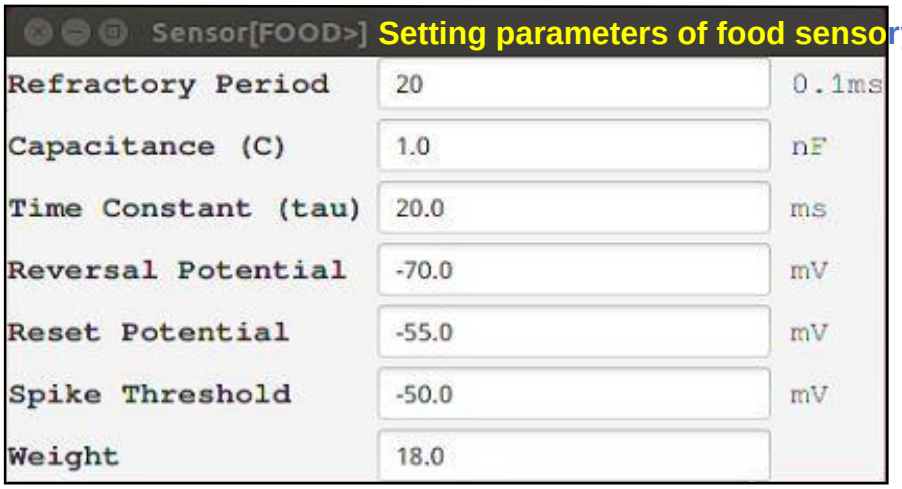
Parameters in GUI	Corresponding parameters in configuration files	Description
Weight	Weight	Synaptic strength = Weight x G(ns)
Conductance (G)	G	



Setting parameters of receptor

Parameters in GUI	Corresponding parameters in configuration files	Description
Time Constant (tau)	Tau	Time constant (ms) of the synaptic receptor
Reversal Potential	RRevPot	Reversal potential (mV) of the synaptic receptor

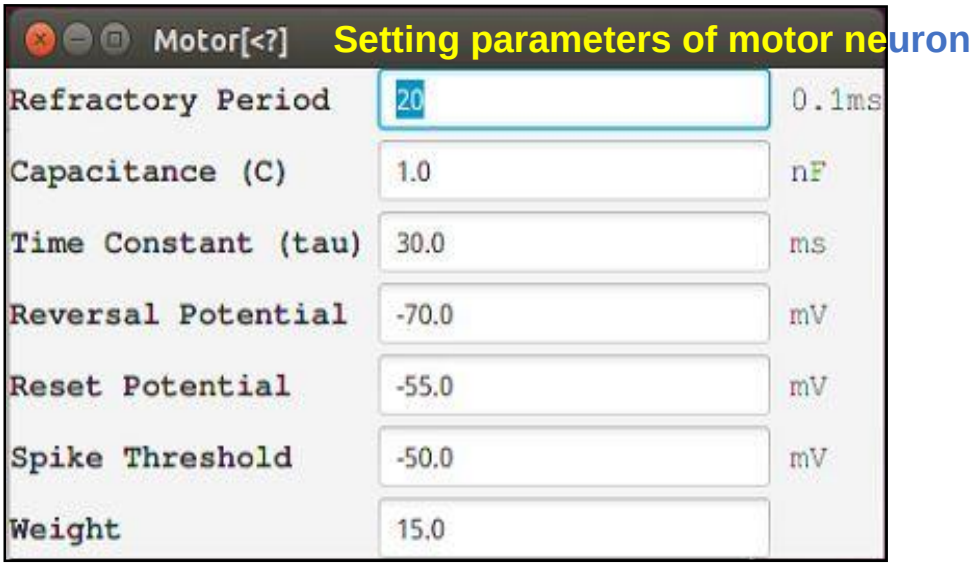
Default parameters for the excitatory and inhibitory neurons		
Parameters in GUI	**Excitatory**	**Inhibitory**
Time Constant (tau)	20.0 ms	20.0 ms
Reversal Potential	0.0 mV	-70.0 mV



Setting parameters of food sensory neuron

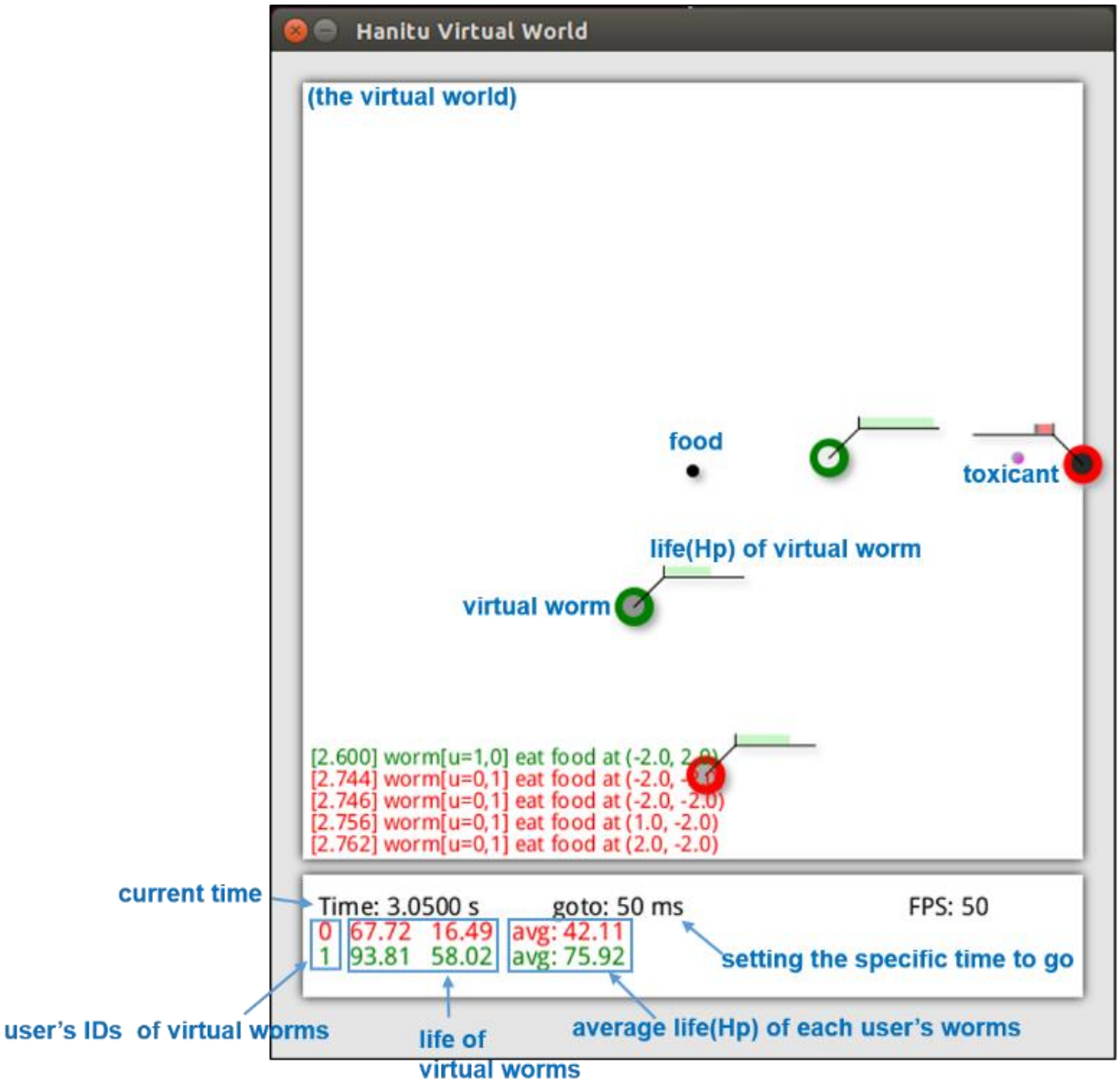
Parameters in GUI	Corresponding parameters in configuration files		Description
Refractory Period	F	SFsilence	Neuron refractory period (0.1 ms)
	T	SCsilence	
	N	NPYSilence	
Capacitance (C)	F	SFcm	Membrane capacitance (nF)
	T	SCcm	
	N	NPYCm	
Time Constant (tau)	F	SFtau	Synaptic time constant (ms)
	T	SCtau	
	N	NPYTau	
Reversal Potential	F	SFvl	Membrane resting potential (mV)
	T	SCvl	
	N	NPYVl	
Reset Potential	F	SFreset	Reset Potential (mV)
	T	SCreset	
	N	NPYReset	
Spike Threshold	F	SFvth	Spike threshold (mV)
	T	SCvth	
	N	NPYVTh	
Weight	F	Weight (In Inputneuron part)	Synaptic weight
	T		
	N	Weight (In NPYTargetNeuron part)	

The GUI used to set parameters of toxicant sensory neuron and NPY neuron is similar to that for food sensory neurons. Abbreviations: “F” for food sensory neurons, “T” for toxicant sensory neurons and “N” for NPY neuron.



Parameters in GUI	Corresponding parameters in configuration files	Description
Refractory Period	Msilence	Neuron refractory period (0.1 ms)
Capacitance (C)	Mcm	Membrane capacitance (nF)
Time Constant (tau)	Mtau	Synaptic time constant (ms)
Reversal Potential	Mvl	Membrane resting potential (mV)
Reset Potential	Mreset	Reset Potential (mV)
Spike Threshold	Mvth	Spike threshold (mV)
Weight	Mweight	Synaptic weight

3.3. Viewing the simulation



After clicking "Run Hanitu and plot" in the "Run" menu of the main GUI, the users bring up a panel (see above) which shows an animation for the virtual worm simulation. Note that the worm movements shown in the GUI is not in real time because the simulation is often much faster than what the GUI shows. The circles represent the worms with horizontal bars indicating the Hp value. The black dots indicate the food sources and the magenta dots are toxicant sources. When a worm eats foods or hits toxicants, the information is displayed at the lower-left corner of the virtual world. The users can press the space button to pause the animation and PgUp/PgDn to change FPS (frame rate per second). The users can enter a number (in msec) then press the enter button to switch to the specified time point.

4. Output files

The Hanitu system has four output files. The former two files are the basic output files and the latter two files present when the users run Hanitu simulations directly (without GUI).

4.1. Locations.txt

The file records the locations(X, Y) and energy levels(Hp) of all virtual worms. The format is as follows:

```
Time(ms)   UserID     WormID     X       Y       Hp
0          0          0          10      -2      99.3599
```

4.2. Spike.txt

The file records spike times of all neurons from all worms. The format is as follows:

```
Time(0.1ms) UserID      WormID      NeuronID         NeuronType
22.7        0           0           3                s
23          0           0           0                d
```

There are four types of neuron in the Hanitu system: s for sensory, m for motor, b for body and d for modulatory.

4.3. Event.dat (when run Hanitu only)

The file describes events of all virtual worms. The format is as follows (excluding first row):

```
Time(0.1ms) UserID      WormID      Event       EventInformation
240         0           2           d           -
241         1           0           l           -
242         0           1           f           [FID]   +10.000000
243         0           1           f           [FID]   HP-full
…
653         0           2           t           [TID]   -10.000000
655         0           2           x           -
656         0           1           b           r
657         1           0           m           [UserID]    [ WormID]
657         1           1           m           [UserID]    [ WormID]
```

There are nine types of events: u for moving forward, d for moving back, l for moving left, r for moving right, f for food getting, t for toxicant touching, x means dead, b for hitting the wall (u/d/l/r in EventInformation is the direction of wall) and m for touching the other worms.

4.4. statistic.csv (when run Hanitu only)

The file summarizes four events of virtual worms. The format is as follows (excluding first row):

```
UID WID total_steps get_food    get_toxi    total_brick touch_worm
0   0   5           1           0           0           0
0   1   5           0           5           0           0
```

Total_steps means the total steps, get_food means the total number for getting food, get_toxi means the total number for touching toxicat, total_brick means the total number for hitting the wall and touch_worm means the total number for touching the other worms.

5. Model and Simulations

5.1. Neuron model

Neuron model Hanitu supports leaky integrate-and-fire model:

$$C_m \frac{dV}{dt} = g_L(V - E_L) + I_{syn},$$

where C_m(nF) is the membrane capacitance, V(mV) is the membrane potential, g_L(ns) is the membrane leak conductance, E_L(mV) is membrane reversal potential and I_{syn}(nA) is the synaptic current. Spike threshold, reset potential, refractory period and spike delay are also implemented in the neuron model. All the parameters are user tunable.

Parameters of model	Parameters in GUI	Parameters in the circuit file
$\boldsymbol{C_m}$	Capacitance (C)	C, SFcm, SCcm, Mcm
$\boldsymbol{g_L}$	Conductance (G) (In body neuron part)	G
$\boldsymbol{E_L}$	Reversal Potential	NRevPot, SFvl, SCvl, Mvl

Note: In the sensory neurons and motor neurons, the membrane leak conductance is set to a fixed value of 2.5 (ns).

5.2. Synapse model

Hanitu supports conductance-based synapse. The synaptic current I_{syn} is given by:

$$I_{syn} = wgs(V - V_{rev}),$$

where w is a weighting factor, g(ns) is the maximum conductance of the synapse, s is the gating variable and V_{rev}(mV) is the reversal potential for the synapse. The gating variable is described by a single exponential decay:

$$\frac{ds}{dt} = -\frac{s}{\tau} + \delta,$$

where τ(ms) is the time constant and δ is a delta function which is ∞ at the time of an spike input and 0 elsewhere. All the differential equations are solved by the fourth-order Runge-Kutta method with a timestep of 0.1 ms.

Parameters of model	Parameters in GUI	Parameters in the circuit file
$\boldsymbol{w}$	Weight	Weight, Mweight
$\boldsymbol{g}$	Conductance (G) (In synapse part)	G
$\boldsymbol{V_{rev}}$	Reversal Potential	RRevPot, SFvl, SCvl, Mvl
$\boldsymbol{\tau}$	Time Constant (tau)	Tau, SFtau, SCtau, Mtau

5.3. Odorant diffusion

In the virtual world, the odorant molecules propagate through the space via diffusion process. However, the Hanitu system does not solve the diffusion equation in real time. Instead, it uses the well-known finite-source solution in which the odorant concentration C at any time and location is given by:

$$\mathrm{C}(\Delta\mathrm{t},\mathrm{r}) = \frac{N_0}{4\pi D(\Delta t)} e^{-(r^2/4D\Delta t)}$$

where $\Delta\mathrm{t}$ is the time after the food or poison is dropped at the source location, r the distance from the source, N_0 the total amount of molecules and D the diffusion coefficient. In Hanitu's default setting D is small and Δt is large so that $\mathrm{C}(\Delta\mathrm{t},\mathrm{r})$ is nearly constant during typical virtual worm simulation periods (several seconds).

6. Obtaining Hanitu

The users can download the Hanitu system package and the sample configuration files of virtual world and the virtual worm circuits from http://hanitu.net.

License information:
The source code of GUI is released under GPL version 3.
The source code of Hanitu (the virtual world) is released under GPL version 3.
The Flysim neural network simulator is currently not open-sourced.

7. The developer team

The Hanitu System is developed by Chung-Chuan Lo laboratory (http://life.nthu.edu.tw/~lablcc/index.html) in National Tsing Hua University, Taiwan. The development team of the current version of Hanitu includes the following members:

Chung-Chuan Lo (cclo@mx.nthu.edu.tw)：Projector leader
Yu-Chi Huang (aiappleg@gmail.com)：Flysim developer
Fang-Kuei Hsieh (fangkui117@gmail.com)：Hanitu developer
Ta-Shun Su (antoniost29@gmail.com)：GUI and scripts developer

Appendix A. Configuration files

The Hanitu system has two configuration files:

1. world_config.wcg：Virtual world configuration file. E.g. the location of worm, diffusion concentration parameters of foods. The users can set filename of circuit configuration files in this file.

2. circuit.ccg：Neural circuit configuration file of virtual worm. The users can change filenames in virtual world configuration file (.wcg).

The users can edit these two parameter files through GUI for avoiding errors.

A.1. Virtual world configuration file (world_config.wcg)

`SetWormInf`	Start of worm-related parameter setting
`UserID=0`	Each virtual world can host worms from multiple users. Here we set the parameters for the first user (ID=0)
`WormID=0`	Each user can have several worms presented in the virtual world. Here we set the first worm (ID=0) for user #0
`InitialX=0`	Worm's initial location in x and y. The unit is one step (0.1 cm) of the worm.
`InitialY=2`	
`Wormsize=1`	Radius of the worm. Same unit as above.
`Time_decay=0.1`	Constant energy level decay per second. (Initial value = 100)
`Step_decay=0.5`	Energy decay per step of the worm
`Filename=Circuit.ccg`	The circuit configuration file of the worm #0
`UserID=0`	
`WormID=1`	
…	(omitted)
`Filename=Circuit2.txt`	

EndSetWormInf	
SetWorld	Now set the virtual world
WorldPar	Define the virtual world parameters
dHP=20	The energy level increased or decreased when a worm touches a food or a toxicant, respectively
GainFF=10 BaselineFF=5	Define the relation between the sensory neuron input rate and the odorant concentration (food to food sensory neuron): firing rate (Hz) = GainFF × [Odor] (mM) + BaselinFF
GainFT=0 BaselineFT=0	(food to toxicant sensory neuron) firing rate (Hz) = GainFT × [Odor] (mM) + BaselinFT
GainTT=0 BaselineTT=0	(toxicant to toxicant sensory neuron) firing rate (Hz) = GainTT × [Odor] (mM) + BaselinTT
GainTF=0 BaselineTF=0	(toxicant to food sensory neuron) firing rate (Hz) = GainTF × [Odor] (mM) + BaselinTF
GainNPY=-25 BaselineNPY=2000	(Ghrelin stimuli to NPY neuron) firing rate (Hz) = GainNPY × [energy level] + BaselineNPY
Boundary=60	The boundary (between -60 and 60 for both x and y) of the virtual world. The unit is 0.1mm.

`Type=0`	Criteria for the simulation termination. Type=0, terminated when all worms die. Type=1, terminated when a worm first touches a food or a toxicant.
`Depth=0.264`	Height of the world. Used for calculating the odorant concentration. Do not alter.
`CountMode=1`	Do not change this parameter. It tells the program that the amount of food in each in each food source does not decrease when the food is eaten by the worms.
`Fixed=0`	Fixing location of virtual worm or not. 1 for fixing and 0 for not.
`FoodLocation`	Now define where the food sources are and other related parameters.
`FID=1`	The first food source (ID=1)
`X=1`	The location (in 0.1 mm)
`Y=2`	
`Count=100`	The food count at each food source
`DiffusionCoef=0.000015`	The diffusion constant of the food molecule $^{cm^2}/_{sec}$
`Concentration=100`	The concentration of the food molecule (mM/count)
`DelayTime=10000`	The virtual worm simulation starts with a delay after the foods are placed in the assigned location. This parameter specified the delay time (0.1 msec)
`FID=2`	If more food sources are need, define them (start with FID=2) before EndFoodLocation.
…	(omitted)
`EndFoodLocation`	End of the definition for all foods
`ToxicantLocation`	Define the parameters for toxicants
`TID=1`	The first toxicant source (ID=1). The meaning of the reset parameters are the same with those for the food sources.
`X=3`	
`Y=2`	
`Count=10`	

```
Diffuse=0.00005
Concentration=10
Delay_time=72000

EndToxicantLocation

EndSetWorld
```

A.2. Circuit configuration files

`%meta.header=circuit_config`
`%meta.version=1.4`
`%meta.createtime=1427965147154`
	Descriptions after % used by GUI. The users just ignore these.

`TotalNeuronNumber=9`	Number of neurons in the circuit. The sensory and motor neurons are not included.
`NeuronID=0`	Defining the first neuron (the neuron ID should start from 0)
`C=0.5`	Membrane capacitance (nF)
`G=25`	Membrane leak conductance (ns)
`MRevPot=-70`	Membrane reversal potential (mV)
`ResetPot=-55`	Reset Potential (mV)
`Threshold=-50`	Spike threshold (mV)
`Refperiod=20`	Refractory period (timestep = 0.1 ms)
`Spikedelay=18`	Spike delay (timestep = 0.1 ms)
`MembranceNoise`	Defining membrane noise (current)
`STD=0.005`	The standard deviation of the membrane fluctuation due to the noise (mV)
`MEAN=0.1`	The mean of the fluctuation (mV)
`EndMembranceNoise`	End of noise definition
`EndNeupar`	End of the definition of somatic parameters for the neuron.
`ReceptorPar`	Start of the synaptic receptor definition
`Receptor=0`	Receptor type ID, starting from 0
`Type=0`	Type of model (currently only support the type 0: one exponential decay, voltage independent)
`Tau=20`	Time constant of the gating variable (ms)
`RRevPot=0`	Channel reversal potential (mV)

`EndReceptor`	End of the synaptic receptor definition for the receptor 0

`Receptor=1`
`Type=0`
`Tau=20`
`RRevPot=-70`
`EndReceptor`
	Defining the second receptor type

`EndReceptorPar`	All receptors have been defined
`Targetneuron=1`	Defining a synaptic connection with a target neuron (neuron ID=1)
`Receptor=0`	Targeting the receptor 0 on the target neuron
`Weight=5`	Synaptic weight (this is just a scaling factor)
`G=2.5`	Synaptic conductance (nS). The synaptic strength = Weight x G
`EndTargetneuron`	End of the definition of the synaptic connection for the target neuron #1

`Targetneuron=8`
`Receptor=0`
`Weight=9`
`G=2.5`
`EndTargetneuron`
	Defining another synaptic connection with neuron #8

`Endneuron`	End of the definition of the neuron #0

`NeuronID=1`
…
`Endneuron`
	Defining the second neuron #1
	(omitted)

`Communication`	Now defining how the circuit interacts with the world
`InputNeuron`	Specifying input (or post-sensory) neurons which neuron receive input from sensory neurons

NeuronID=0	Neuron 0 receiving sensory input
Receptor=0	The sensory input target the receptor 0 on neuron 0
Weight=1	Synaptic weight for the sensory neuron input
G=2.5	Synaptic conductance (nS)
Type=0	type of sensory input (0=food, 1=toxicant)
Direction=0	Receiving sensory neuron input from the top side (0, 1, 2, 3 for top, down, left, right)
NeuronID=2	Neuron 2 also receiving sensory input
Receptor=0	
Weight=1	
G=2.5	
Type=0	
Direction=1	
NeuronID=4	
…	(omitted)
Direction=2	
NeuronID=6	
…	(omitted)
Direction=3	
EndInputneuron	
NPYTargetNeuron	Defining the target neuron of NPY neuron
NeuronID=9	Neuron 9 receiving NPY neuron input
Receptor=0	The NPY neuron input target the receptor 0 on neuron 0
Weight=2.000000	Synaptic weight for the NPY neuron input
G=1.000000	Synaptic conductance (nS)
…	(omitted)
EndNpyPar	

`OutputNeuron`	Defining how the circuit sends output to motor neurons. Only four output (or pre-motor) neurons can be specified here.

`NeuronID=1`
`NeuronID=3`
`NeuronID=5`
`NeuronID=7`
	Neuron 1, 3, 5, 7 sending output to the motor neuron on the top, down, left, right side

`EndOutputNeuron`	
`BodyPar`	Now defining sensory and motor neurons on the body walls
`MCm=25`	Membrane capacitance (nF)
`MTau=10`	Synaptic time constant (ms). This is the synapse for the connection from the output neurons to the motor neurons
`MWeight=10`	Synaptic weight (synaptic strength = synaptic weight x synaptic conductance)
`MSilence=20`	Neuron refractory period (0.1 ms)
`MVTh=-50`	Spike threshold (mV)
`MVl=-70`	Membrane resting potential (mV)
`MReset=-55`	Reset Potential (mV)

`SFCm=25`
`SFTau=20`
`SFWeight=10`
`SFSilence=20`
`SFVTh=-50`
`SFVl=-70`
`SFReset=-55`
	Setting the parameters for the food sensory neurons.

`STCm=25`
`STTau=10`
`STWeight=10`
`STSilence=20`
`STVTh=-50`
	Setting the parameters for the toxicant sensory neurons

```
STVl=-70
STReset=-55

NPYCm=1.000000
NPYTau=20.000000
NPYWeight=5.000000
NPYSilence=20
NPYVTh=-50.000000
NPYVl=-70.000000
NPYReset=-55.000000

EndBodyPar

EndCommunication
```

Setting the parameters for NPY neuron

A.3. File format changes in configuration file for Hanitu v.1.4

There are several modification of configuration files in Hanitu v.1.4. If users want to use files of previous version (versions before v.1.4), you need to change and add some parameters by yourselves.

■ Virtual world configuration file

1. Delete `%meta.*` (rows at the beginning of files)
2. The following is the modification list for parameters:

Previous version	v.1.4
SetWormInf	
Time_decay	TimeDecay
Step_decay	StepDecay
SetWorld	
Nutrient	dHP
TransformA	GainFF
TransformA_FT	GainFT
TransformA_TF	GainTF
TransformA_TT	GainTT
-	GainNPY
TransformB	BaselineFF
TransformB_FT	BaselineFT
TransformB_TF	BaselineTF
TransformB_TT	BaselineTT
-	BaselineNPY
Food/ToxicantLocation	
Diffuse	DiffusionCoef
Delay_time	DelayTime

■ Circuit configuration files

1. Delete `%meta.*` (rows at the beginning of files)
2. The following is the modification list for parameters:

Previous version	v.1.4
Total_neuron_number	TotalNeuronNumber
Neuron definition	
NRevPot	MRevPot
-	ResetPot
Communication: InputNeuron/ OutputNeuron	
NeuID	NeuronID
Communication: NPYTargetNeuron	
-	NPYTargetNeuron
-	NeuronID
-	Receptor
-	Weight
-	G
-	EndNpyPar
BodyPar	
-	MReset
-	SFReset
SCcm	STCm
SCtau	STTau
SCweight	STWeight
SCsilence	STSilence
SCvth	STVTh
SCvl	STVl
- / SCreset	STReset
-	NPYCm
-	NPYTau
-	NPYWeight
-	NPYSilence
-	NPYVTh
-	NPYVl
-	NPYReset